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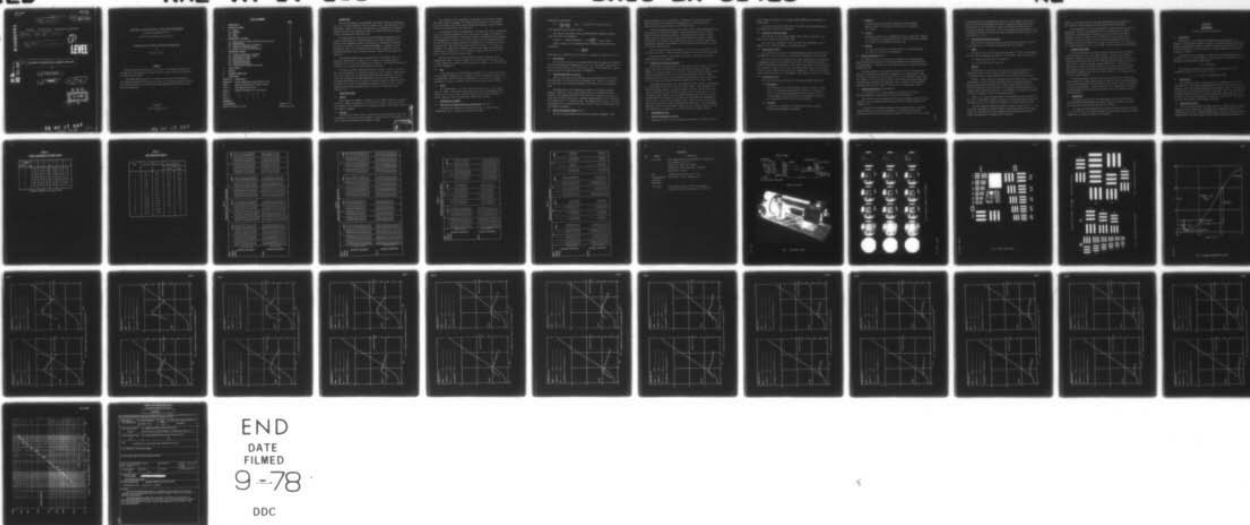
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by

(10) Madeline J. Fryer

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A TECHNIQUE FOR OBTAINING FILM THRESHOLD MODULATION

by

Madeline J. Fryer

SUMMARY

↙ The Film Threshold Modulation is a measure of performance which can be combined with lens Modulation Transfer Function figures to give an assessment of lens/film performance.

This Memorandum describes the techniques developed for obtaining the Film Threshold Modulation Curves for any type of film using a Resolution Camera. The results achieved for the two films tested (Kodak and Ilford Class L-5-M) are also presented. ↘

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1 INTRODUCTION

The main requirement of photography, when used in aerial reconnaissance work, is to record information from the terrain below. The efficiency of the photographic system to act as a storage device is determined by the physical characteristics of the lens and film and to a lesser extent by the camera design, environment and conditions, etc.

The image quality of film for aerial photography has generally been studied by measuring its limiting resolution at a target contrast of 0.2. However, this measurement cannot be combined with the Modulation Transfer Function of the lens¹ to give the system performance. A measure of film performance, which can be convoluted with lens MTF, is known as the Film Threshold Modulation and this report describes a method for obtaining this parameter.

Film Threshold Modulation is defined here as the minimum depth of modulation required in the image of a test target, at any given spatial frequency, for it to be just resolved by an observer. The figure obtained will depend on the film used and its processing conditions.

Two medium contrast, medium speed films, currently in service with the RAF, were investigated. A resolution camera was used to produce target images on the test films, for various target modulations and exposures. The test films were processed in the RAE sensitometric agitator which simulates the processing method used in the Services. The main results for these two films are shown in the form of Film Threshold Modulation curves, in which target modulation versus peak resolving power is plotted on logarithmic axes. (Figs 22, 23).

2 RESOLUTION CAMERA

2.1 Design

This camera was designed to produce a set of target images of a resolution chart for a range of exposures, on a strip of test film. A diagram covering the features of the construction of the camera is shown in Fig 1 with a view of the complete equipment.

2.2 Exposure

An electronic flash is used to expose the resolution target on the film, the sequence of operations being arranged to ensure that the film sample is at rest in the focal plane when the exposure is made.

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The intensity of the illumination can be varied in two ways to enable the correct range of exposure, for films of various speeds, to be obtained. Firstly the power of the flash can be halved and secondly, a neutral density filter can be positioned in the light path.

By altering the size of an aperture in the light path, which is positioned close to a diffuser illuminated by the source near the target, the amount of light on a second diffuser is varied and a range of exposures (from overexposed to underexposed) is obtained on a strip of test film. The varying apertures are a set of holes arranged around the circumference of a mechanically driven circular plate. The area of each hole varies by a factor of $1:\sqrt{2}$ from its neighbour. To produce more consistent results three images are produced per aperture size, resulting in a 3×15 matrix of images on each strip of test film, a section of which is shown in Fig 2.

For the films tested in this work the electronic flash was set for maximum power and a 1.5 neutral density filter was placed in the light path. A colour temperature correction filter was used to produce a colour temperature of 3500 K (Appendix B).

2.3 Lens

A very high quality Zeiss reduction lens (NA 0.2) is used in the camera, with good MTF performance over the range of spatial frequencies required and a substantially flat field over a 2mm diameter circle in the focal plane. It is designed to be used at a reduction of X10 with an optical throw of 427mm.

2.4 Target

The standard USAF 3 bar target has been chosen for use in the camera (Fig 3). Table 1 shows target group numbers and their corresponding spatial frequencies in lines per mm. Section 3 describes the method employed to produce targets of various modulations using a master target.

3 MANUFACTURE OF TARGETS

3.1 Definitions of Target Modulation and Contrast (see Ref 1)

The modulation expresses the maximum variation of peak to trough transmittance and is constant across any given target.

Modulation is defined as:

$$M = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \quad \text{where } I \text{ represents the light intensity.}$$

This expression varies between 0 and 1.

The contrast was taken to be the diffuse density difference between target bars and the background.

$$\text{Contrast} = \text{Density Difference} = \log \left(\frac{I_{\max}}{I_{\min}} \right) = D_{\max} - D_{\min}$$

Target contrast (C) and modulation (M) are related by the following expression:

$$M = \frac{10^C - 1}{10^C + 1}$$

(NB Modulation is numerically very similar to contrast for values up to 0.7).

3.2 Requirements

Low contrast versions of the standard USAF three bar target were required with various modulations ranging from 0.7 to 0.01. The target image needed to have an average density to suit the lighting level of the camera and a uniform density in both the target bars and the background.

3.3 Sensitive Material for Targets

Various films were tried including, line films and graphic arts films. The film found to be most suitable was Kodak SO 343. This is a slow speed, very fine grain, high resolution emulsion coated onto a 0.007 in polyester base.

The Kodak film, used for making the targets, was chosen as having adequate resolution to give correct shaped bars at the maximum resolution expected. The maximum resolution of the test film is likely to be about 100 lines per mm and this would give a reading of group number 3-3 (10.3 lines per mm) because of the $\times 10$ reduction lens. The Kodak SO 343 resolves to at least group number 6-6 (114 lines per mm) and is thus at least ten times better than the maximum requirement.

3.4 Method for Standard Target (Fig 3)

The film was pre-exposed using a De Vere enlarger, arranged to give

uniform illumination on the baseboard. To prevent reflections matt black paper was taped to the baseboard. Pre-exposure was controlled to give a uniform overall density of about 0.3 after processing.

The master target was taped to the contact printer platen and masked with black paper; the pre-exposed film was then contact-printed with the master target at various different exposures. During the second exposure the high contrast master target acted as a mask thus resulting in a range of target modulations. It was found that giving several pieces of film the same second exposure but varying the development time for each made the production of very low contrast targets easier.

The film was developed using Teknol 1+1 at 20°C, for times between 1 and 3 minutes, in a dish. Continuous gentle agitation was given during processing.

Using this method it was possible to produce a wide range of suitable targets using simple equipment.

3.5 Method for Low Contrast Targets

At the very low modulations (0.06 and less), even the largest bars on the target could not be resolved and so two new "master" targets were made (Figs 4, 5) to enable group (-1) to be used. The target shown in Figure 4 has spatial frequencies from 17.8 to 7.2 lines per mm and was used for target modulations of 0.044 and 0.052; the target shown in Figure 5 has a range from 8.0 to 5.0 lines per mm and was used for modulations of 0.024 and 0.038.

The larger group, Group (-1), was obtained at high contrast by producing a x2 enlargement of Group (0), from the master target. This enlargement was found to be larger than the resolution camera's field of view because of the limited field of the Zeiss lens ie the target had to be contained in a circle of diameter 20mm. Thus the two new "master" targets (used for the very low contrast work) were produced by cutting up the enlargement and arranging the sets of bars to fit into the required circles. High contrast contact prints were made of the above to give the required black bars on a white background. These were used as the new "master" targets and low contrast targets were made from them in the way described in section 3.4 for the standard target.

4 EXPERIMENTAL METHOD

4.1 Initial Preparation of Camera

Tests were carried out to determine the conditions required to give the

correct range of exposure, ie to produce images ranging from overexposed to underexposed.

Tests were also made to ensure that the target was centralised and that the optimum focus position was obtained.

4.2 Production of Target Images

The film was cut into strips (230mm x 35mm) which were placed in the camera with emulsion side facing the lens.

For each target modulation a strip of test film, containing a set of images for the various exposures, was produced (Fig 2).

4.3 Sensitometric Tests

All sensitometric tests are to RAE Purchasing Specification PH400 (Ref 2) and Appendix A covers the aspects of sensitometry appropriate to this study.

For each strip of film exposed in the camera a graded series of exposures (a wedge) was required on a second strip of film. This wedge was exposed on a modified Eastman IIB sensitometer. The light source used in the sensitometer was a tungsten filament, 2850 K lamp with a Chance OB8 colour correction filter to give a colour temperature of 3500 K (see Appendix B). This is the standard colour temperature used in air photography. The exposure time was 1/100 second.

4.4 Processing of Film

All the film was processed under the following standard conditions:

(a) Development

The developer used was May and Baker 'Exprol A', (which is that used in the RAF processing machines) diluted 1 to 1 volumes in water. The developer was prepared immediately prior to use. The development was carried out with a high degree of agitation at a temperature of $33^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ for 30 seconds.

(b) Stop Bath

A stop bath, consisting of a 2% solution of acetic acid was used between development and fixing.

(c) Fixation

A rapid fixing bath was used, consisting of May and Baker Amfix, diluted 1 to 3 volumes in water, with a fixing time of 1 minute.

(d) Washing

Washing was carried out in running water for not less than 5 minutes at a temperature of approximately 20°C. These conditions of washing are intended for sensitometric purposes only.

(e) Drying

The film, after removal of surface moisture from front and back, was hung up to dry at room temperature.

4.5 Density Measurement (Ref 3)

The densities of the test strips were measured on a Photolog Digital colour densitometer (manufactured by Medical and Electronic Instrumentation). This densitometer is calibrated to read diffuse density, as defined in British Standard BS 1384.

The wedge densities were measured and used to plot the characteristic curve of the emulsion (as described in Appendix A). A characteristic curve was (Fig 6) thus produced for each strip of test film containing target images. This enabled a check to be made to ensure that standard developing conditions were maintained throughout the experiment, since a change in the developing conditions would vary the shape or position of the characteristic curve.

4.6 Resolution Readings (see Appendix B)

The resolution of the target images was assessed with a Vision Engineering Dynascope (Microsystem 80 projection microscope).

The resolution result recorded was the average reading, obtained by three observers, of the maximum resolution obtained from the three images at each exposure level.

To position the resolution figures on the same log E axis as the film characteristic curve it was only necessary to establish one point with precision, since the exposure levels are related in a series $1:\sqrt{2}$ (or 0.15 log)

by the aperture disc as explained (section 2.2). The exposure chosen was the third set from the over-exposed end, thus by reading the density patch and relating this to the characteristic curve the resolution reading could be positioned along the $\log E$ axis. With the plotting scale established a curve of resolution versus \log exposure was drawn, enabling the peak resolution to be found (Figs 7 to 21).

4.7 Film Threshold Modulation Curves

By plotting the target modulation versus the peak resolution, achieved at that modulation, the Threshold Modulation Curve was obtained.

5 FILMS

The films tested in this report were both Class 'L', that is panchromatic film for aerial photography at medium or low altitudes. The test films were:

- (1) Kodak, type 2645 (SO 531), batch 213.
- (2) Ilford, FP3 aerial, batch 52D.

6 RESULTS

Fifteen runs were completed, for each film, with target modulations ranging from 0.66 to 0.021. Table 2 shows the test numbers and their corresponding target contrasts/modulations and the peak resolution results.

Tables 3, 4 and 5 give the resolution results obtained using the standard target; Table 6 gives the results from the special low-contrast targets. The tables show the observations of the three readers and their mean from which the resolution curves are drawn. All observers found reading the lower contrast targets much more difficult. In the tables the columns of resolution results are arranged in order of decreasing exposure.

Figs 7 to 21 show the Characteristic and Resolution Curves obtained for each test. Each figure presents the curves, at a particular target modulation, for both test films thus enabling a comparison to be made between the two.

The Film Threshold Modulation Curves are shown in Figs 22 and 23. It is clear that a straight line drawn through the data points provides the simple curve fit. This agrees with the findings of other workers who have made similar measurements (for example, Ref 1 pp 66-72).

However, it is believed that the current work has extended the FMT data to lower values of target contrast than have been measured previously.

It is interesting to note that although the measured values for the two films agree closely at low modulations there is evidence that at higher modulations the Kodak film (the slower of the two) gives an increase in threshold resolution compared with the Ilford film. This trend is also observed in the specification testing of these two materials, where the threshold resolution is measured at a single contrast value of 0.2 (equivalent to a target modulation of 0.23) with longer time processing using D19 developer.

7 POSSIBLE FUTURE WORK

It would be desirable to obtain Threshold Modulation Curves, using the technique described, for a wide range of films. In this way it would be possible to predict the most suitable lens/film combination for a certain application, bearing in mind that the Threshold Modulation Curve only applies when the film is used at optimum exposure conditions. It would also be informative to obtain the Modulation Curves for a range of films at various given exposures which would enable different lens/film combinations to be assessed for exposure conditions other than the ideal, *eg* in conditions likely to produce under-exposure.

The minimum target modulation used in this work was 0.021. For lower target modulations larger target groups are required but the resolution camera has not been designed for such low contrast work and thus will not accommodate the larger target groups. A system that uses a 1:1 reproduction ratio would be more suitable and this could be achieved by optical or possibly, contact printing methods.

8 CONCLUSIONS

A technique, described in this Memorandum, has been established for obtaining Film Threshold Modulation Curves. Using this method curves have been obtained for Kodak and Ilford Class L-5-M films.

The range of target modulations that can be studied using this technique is 1.0 to 0.02. If it is found necessary to obtain results using lower target modulations a different approach must be found.

Appendix A

SENSITOMETRY

(see section 4.3, 4.5 and Ref 3)

A.1 Introduction

Sensitometry is the accurate measurement and interpretation of the response of a photographic emulsion to light. The general features obtained by exposing a photographic material to light is shown by the characteristic curve in which the density of developed deposit is plotted against the log exposure producing it (Fig 6).

The density (D) of an image is a measure of its light-stopping power in log terms. If I_0 is the intensity of light incident on a film and I_t is the intensity of the transmitted light their:

$$D = \log (I_0/I_t)$$

The exposure is defined as the product of the intensity I of the illumination and the time t for which it acts:

$$E = I \times t \text{ (units: candela-metre-seconds)}$$

A.2 Sensitometer

The sensitometer gives a controlled series of exposure to the strip of film under test, the exposure being modulated either by a time scale or by an intensity scale. The modified Eastman IIB sensitometer, used in this work, has an intensity scale obtained by means of a step wedge. This is a graded series of neutral densities such that the optical density increment from one step to the next is 0.15, thus the exposure is varied by a factor of $\sqrt{2}$. The exposed strip is then developed under standard conditions.

A.3 Characteristic Curve

The curve obtained, when the diffuse densities, obtained from the exposed wedge, are plotted against the logarithms of the exposure, is known as the 'characteristic curve'. Different characteristic curves are given by different emulsions and by the same emulsion under different processing conditions but

they all follow a similar trend. Characteristics of this curve are discussed by reference to a typical curve (Fig 6).

The density observed when the curve is parallel to the log exposure axis is known as the fog and it is of chemical origin. In this region the exposing light has been too weak to produce any effect. With increasing exposure the curve begins to rise, the *toe* of the curve, and the slope increases to the *straight-line* region where increases in log exposure produce proportional increases in density. Eventually a maximum is reached, the *shoulder* of the curve, where the density remains constant during a further substantial increase in the exposure.

Speed expresses the sensitivity of an emulsion to light. In air photography the point on the curve corresponding to a density of 0.4 above fog is defined as the "speed-point". The speed is taken as the log of the reciprocal of the exposure in candela metre seconds at the speed point.

The contrast of an emulsion is related to the gradient of the "straight-line" region. For air photography it is defined as the slope of the straight line joining the speed point to a point on the characteristic curve at 1.0 log units greater exposure.

Appendix B

B.1 Colour Temperature

The colour quality of some light sources can be expressed in terms of colour temperature. This is a measure which defines the colour of a light source relative to the visual appearance of the light radiated by a theoretically perfect radiator or black body, heated to incandescence. The colour temperature is expressed in degrees Kelvin (K). By use of colour correction filters, the colour temperature of a light source can be modified.

B.2 Resolving Power (see Refs 1 and 3)

Resolving power is a measure of the ability of a photo-optical system or component to produce and detect the smallest separation of details within an image.

It is measured in photographic practice by forming an image of a test object consisting of a parallel bar on a denser background, with equal mark space ratio and examining the image through a microscope under adequate magnification to determine the finest pattern in which the bars can be distinguished separately. The numerical value of resolving power is expressed in lines per millimeter from the relationship:

$$\text{Spatial frequency (lines/mm)} = \frac{1}{\text{pitch of bars in mm}} \cdot$$

Table 1SPATIAL FREQUENCIES OF TARGET GROUPS

<div>Number Group</div>	1	2	3	4	5	6
-1	0.50	0.56	0.64	0.72	0.80	0.89
0	1.00	1.12	1.28	1.43	1.60	1.78
1	2.00	2.25	2.55	2.88	3.20	3.57
2	4.00	4.50	5.12	5.72	6.40	7.15
3	8.00	9.00	10.20	11.55	12.80	14.30
4	16.0	18.0	20.5	23.0	25.6	28.6
5	32.0	36.0	40.8	46.0	51.0	57.0

(Spatial Frequency in lines per mm)

Table 2PEAK RESOLUTION RESULTS

Test	Contrast	Modulation	Peak Resolution	
			Ilford	Kodak
1	0.69	0.66	80.0	102.0
2	0.57	0.58	65.0	81.0
3	0.51	0.53	61.5	64.5
4	0.38	0.41	53.5	62.0
5	0.28	0.31	38.5	48.5
6	0.19	0.21	32.5	39.0
7	0.12	0.14	25.5	26.5
8	0.11	0.13	23.5	26.5
9	0.08	0.09	19.0	17.5
10	0.065	0.075	13.5	14.5
11	0.050	0.058	12.5	13.5
12	0.045	0.052	11.0	11.5
13	0.038	0.044	10.0	9.5
14	0.033	0.038	7.0	8.0
15	0.021	0.024	5.5	5.5

Table 3
RESOLUTION RESULTS IN LINES PER MM

TEST READER	1				2				3				4			
	1	2	3	MEAN	1	2	3	MEAN	1	2	3	MEAN	1	2	3	MEAN
ILFORD ↓ DECREASING EXPOSURE	57.2	57.2	57.2	57.2	45.0	51.2	45.0	47.1	40.0	45.0	40.0	41.7	40.0	45.0	40.0	41.7
	64.0	64.0	64.0	64.0	40.0	51.2	45.0	45.4	40.0	51.2	40.0	43.7	45.0	45.0	40.0	43.3
	71.5	64.0	64.0	66.5	45.0	57.2	51.2	51.1	40.0	57.2	40.0	45.7	45.0	51.2	45.0	47.1
	71.5	71.5	71.5	71.5	51.2	64.0	51.2	55.5	45.0	57.2	51.2	51.1	45.0	51.2	45.0	47.1
	71.5	71.5	71.5	71.5	51.2	71.5	51.2	58.0	51.2	64.0	51.2	55.5	51.2	51.2	45.0	49.1
	80.0	80.0	80.0	80.0	57.2	71.5	51.2	60.0	51.2	64.0	51.2	55.5	51.2	57.2	51.2	53.2
	80.0	71.5	80.0	77.2	64.0	80.0	51.2	65.1	51.2	71.5	51.2	58.0	51.2	57.2	51.2	53.2
	80.0	71.5	71.5	74.3	64.0	80.0	51.2	65.1	64.0	71.5	51.2	64.2	51.2	51.2	45.0	49.1
	71.5	57.2	71.5	66.7	57.2	80.0	51.2	62.8	51.2	71.5	51.2	58.0	35.7	45.0	35.7	38.8
	57.2	45.0	57.2	53.1	51.2	71.5	51.2	58.0	45.0	64.0	51.2	53.4	32.0	40.0	32.0	34.7
	45.0	35.7	45.0	41.9	45.0	57.2	40.0	47.4	40.0	45.0	45.0	43.3	20.0	22.5	14.3	18.9
	32.0	25.5	28.8	28.8	35.7	45.0	28.8	36.5	35.7	45.0	35.7	38.8	11.2	14.3	10.0	11.8
KODAK ↓ DECREASING EXPOSURE	64.0	71.5	57.2	64.2	45.0	57.2	51.2	51.1	40.0	45.0	40.0	41.7	40.0	45.0	40.0	41.7
	80.0	71.5	71.5	74.3	51.2	64.0	51.2	55.5	45.0	51.2	45.0	49.1	45.0	51.2	40.0	45.4
	90.0	80.0	71.5	80.5	51.2	71.5	51.2	58.0	45.0	57.2	45.0	49.1	51.2	57.2	45.0	51.1
	90.0	80.0	80.0	83.3	57.2	80.0	57.2	64.8	51.2	57.2	51.2	53.2	51.2	64.0	51.2	55.5
	102.0	90.0	90.0	94.0	57.2	80.0	57.2	64.8	51.2	71.5	51.2	57.9	57.2	64.0	57.2	59.5
	102.0	102.0	90.0	98.0	71.5	90.0	71.5	77.7	57.2	71.5	57.2	62.0	57.2	71.5	57.2	62.0
	102.0	102.0	102.0	102.0	71.5	90.0	71.5	77.7	57.2	71.5	57.2	62.0	51.2	71.5	57.2	60.0
	102.0	102.0	102.0	102.0	71.5	90.0	71.5	77.7	64.0	71.5	57.2	64.2	45.0	51.2	45.0	47.1
	90.0	80.0	80.0	83.3	80.0	90.0	71.5	80.5	57.2	71.5	57.2	62.0	35.7	40.0	40.0	38.6
	80.0	71.5	71.5	74.3	71.5	80.0	57.2	69.6	51.2	64.0	45.0	53.4	25.5	28.8	25.5	26.6
	67.2	51.2	51.2	53.2	51.2	71.5	45.0	55.9	35.7	45.0	40.0	40.2				
	40.0	40.0	35.7	38.6	40.0	51.2	40.0	43.7	28.8	32.0	25.5	28.8				
	22.5	10.0	22.5	22.5	25.5	32.0	22.5	26.7	10.0	14.3						

Table 5

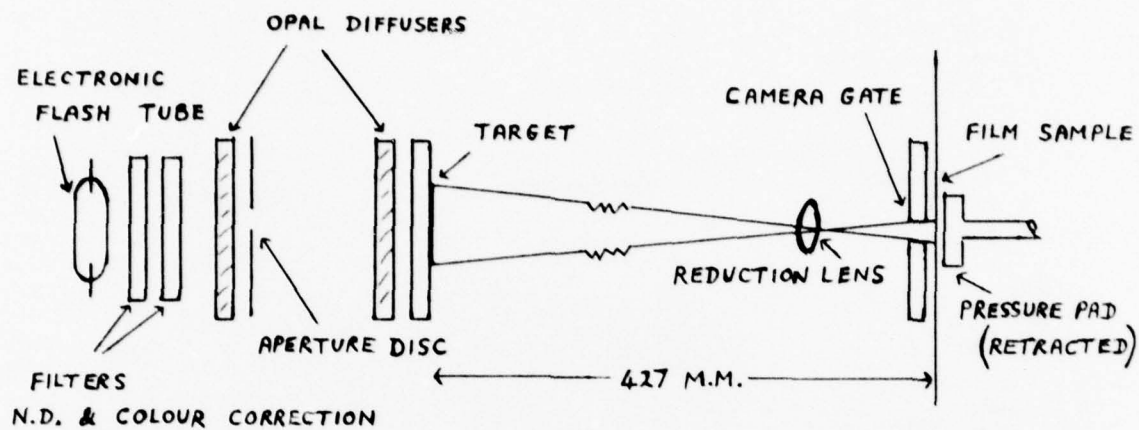
RESOLUTION RESULTS IN LINES PER mm

TEST READER	2				10				11			
	1	2	3	MEAN	1	2	3	MEAN	1	2	3	MEAN
ILFORD DECREASING EXPOSURE	11.2	11.2	11.2	11.2	10.0	-	-	10.0	-	-	-	-
	12.8	12.8	11.2	12.3	-	-	-	-	-	10.0	-	-
	12.8	12.8	12.8	12.8	-	-	-	-	-	-	-	-
	12.8	12.8	12.8	12.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	12.8	12.8	12.8	12.8	11.2	11.2	11.2	11.2	10.0	12.8	10.0	10.9
	14.3	14.3	12.8	13.8	11.2	12.8	12.8	12.3	11.2	12.8	11.2	11.7
	14.3	17.8	14.3	15.5	12.8	14.3	12.8	13.3	11.2	12.8	11.2	11.7
	16.0	20.0	14.3	16.8	14.3	14.3	12.8	13.8	11.2	12.8	11.2	11.7
	17.8	20.0	20.0	19.3	11.2	14.3	11.2	12.2	12.8	14.3	11.2	12.8
	17.8	20.0	17.8	18.5	10.0	12.8	11.2	11.3	12.8	12.8	11.2	12.3
KODAK DECREASING EXPOSURE	16.0	17.8	12.8	15.5	-	-	-	-	-	-	-	-
	10.0	12.8	10.0	10.9	-	-	-	-	-	-	-	-
	11.2	9.5	10.0	10.2	-	11.2	-	-	-	-	-	-
	11.2	9.5	10.0	10.2	-	10.0	10.0	10.0	-	-	-	-
	11.2	12.8	10.0	11.3	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	11.2	12.0	11.2	11.5	11.2	14.3	11.2	12.2	10.0	11.2	10.0	10.4
	12.8	12.8	12.8	12.8	11.2	12.8	11.2	11.7	11.2	11.2	10.0	10.8
	14.3	12.8	12.8	13.3	11.2	12.8	12.8	12.8	12.8	12.8	11.2	12.3
	16.0	17.8	12.8	15.5	12.8	12.8	12.8	14.4	14.3	12.8	11.2	12.8
	17.8	20.0	14.3	17.4	14.3	16.0	12.8	14.3	14.3	14.3	11.2	13.3
KODAK DECREASING EXPOSURE	17.8	17.8	12.8	16.1	12.8	12.8	11.2	12.3	12.8	14.3	12.8	13.3
	17.8	17.8	12.8	16.1	-	-	-	-	11.2	11.2	11.2	11.2
	12.8	12.8	10.0	11.9	-	-	-	-	-	-	-	-
	10.0	11.2	10.0	10.9	-	-	-	-	-	-	-	-

REFERENCES

<u>No.</u>	<u>Author</u>	<u>Title, etc</u>
1	G.C. Brock	Micro-image quality in photographic considerations for aerospace (pp 42-72). Edited by H. Hall and H. Howell. Published by Ilek Corporation, Lexington Massachusetts (1965)
2	RAE Instrumentation and Trials Department	Purchasing Specification No. Ph 400 Fifth issue. Date: February 1977.
3	G.C. Brock	The physical aspects of aerial photography. Published by Dover Publications, Inc, New York

Fig 1



Schematic diagram

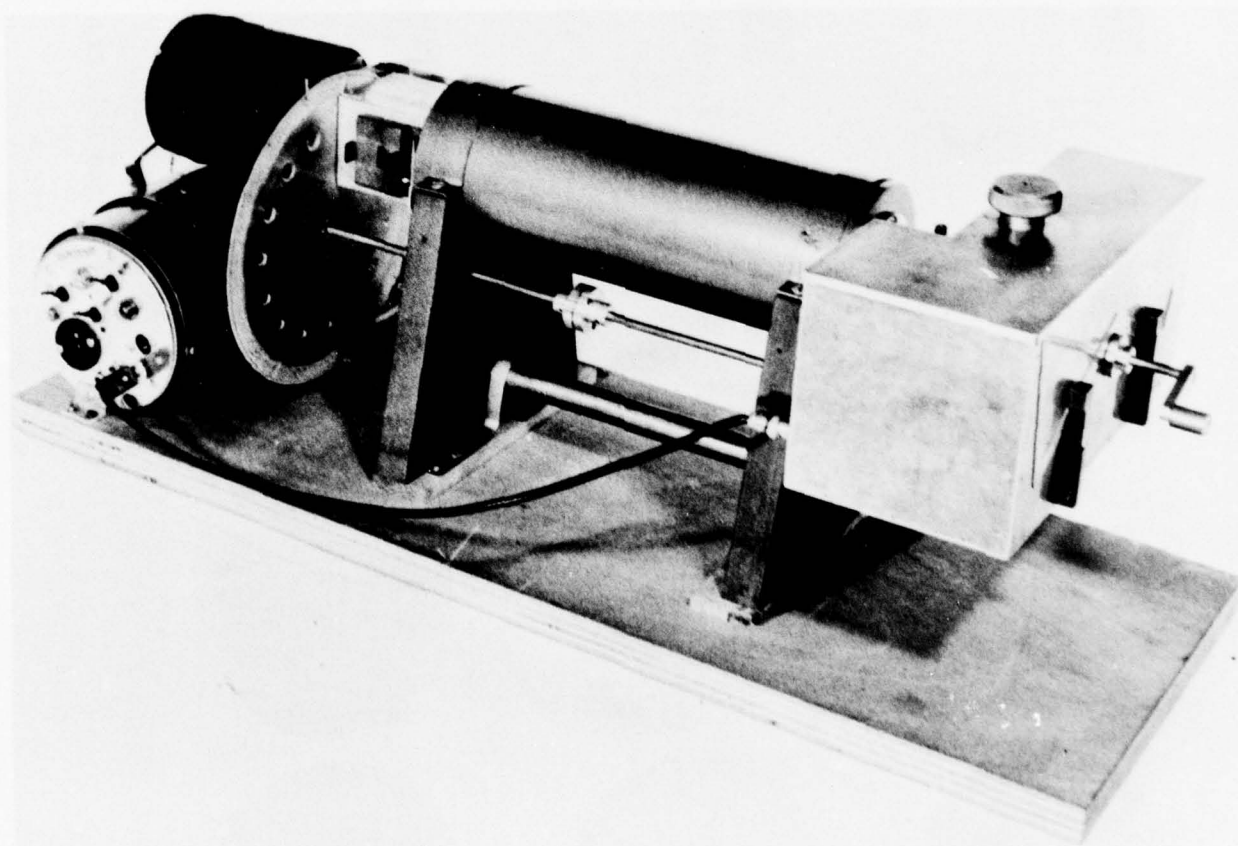


Fig 1 Resolution camera

Fig 2



Fig 2 Resolution Images ($\times 10$ enlargement)

Fig 3

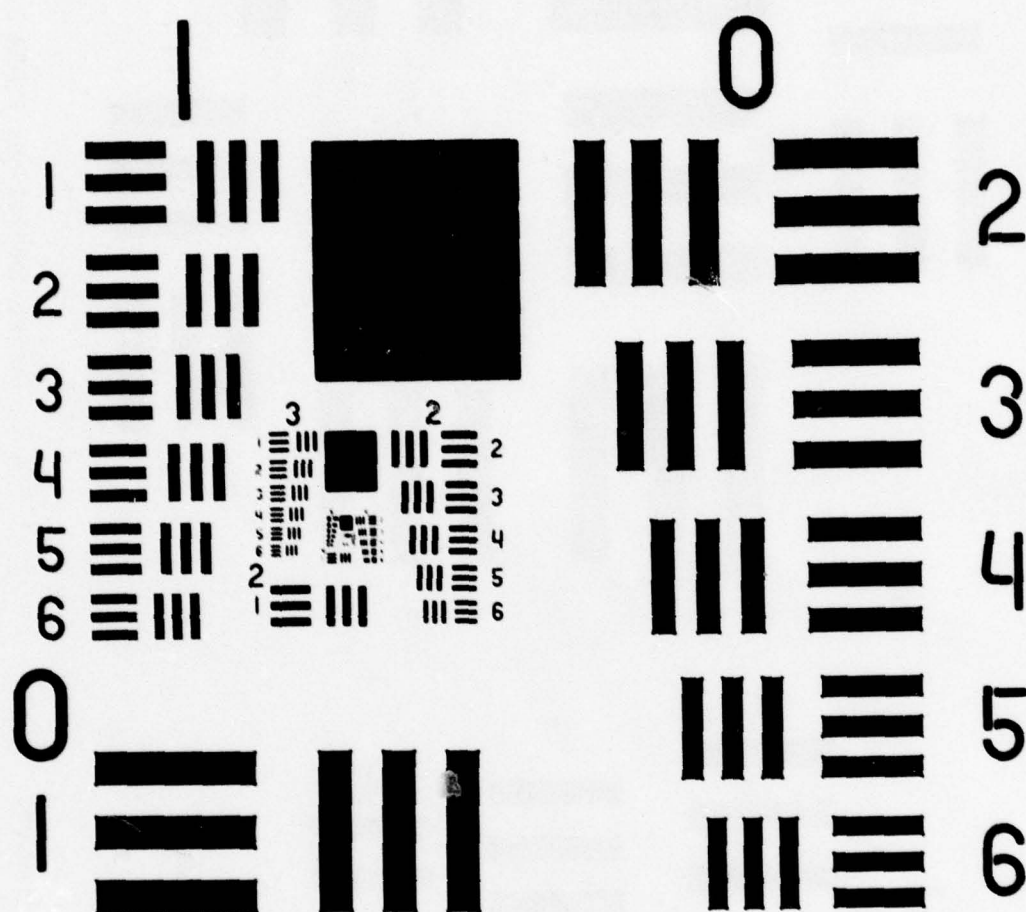


Fig 3 USAF 3 Bar Target

Fig 4 & 5

Low Contrast Target Configurations

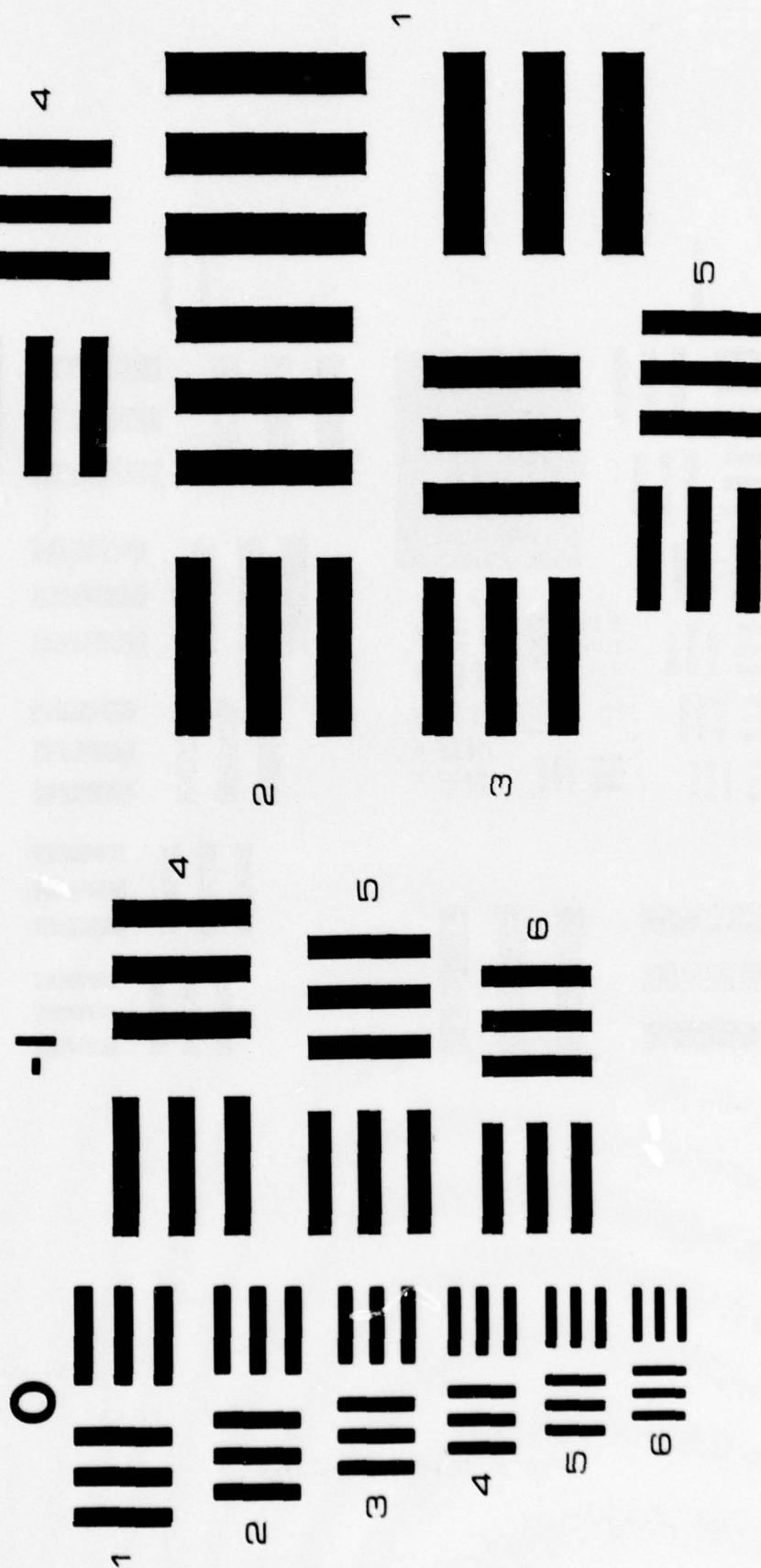


Fig 4 Target Modulations 0.044 0.052

Fig 5 Target Modulations 0.038 0.024

Fig 6

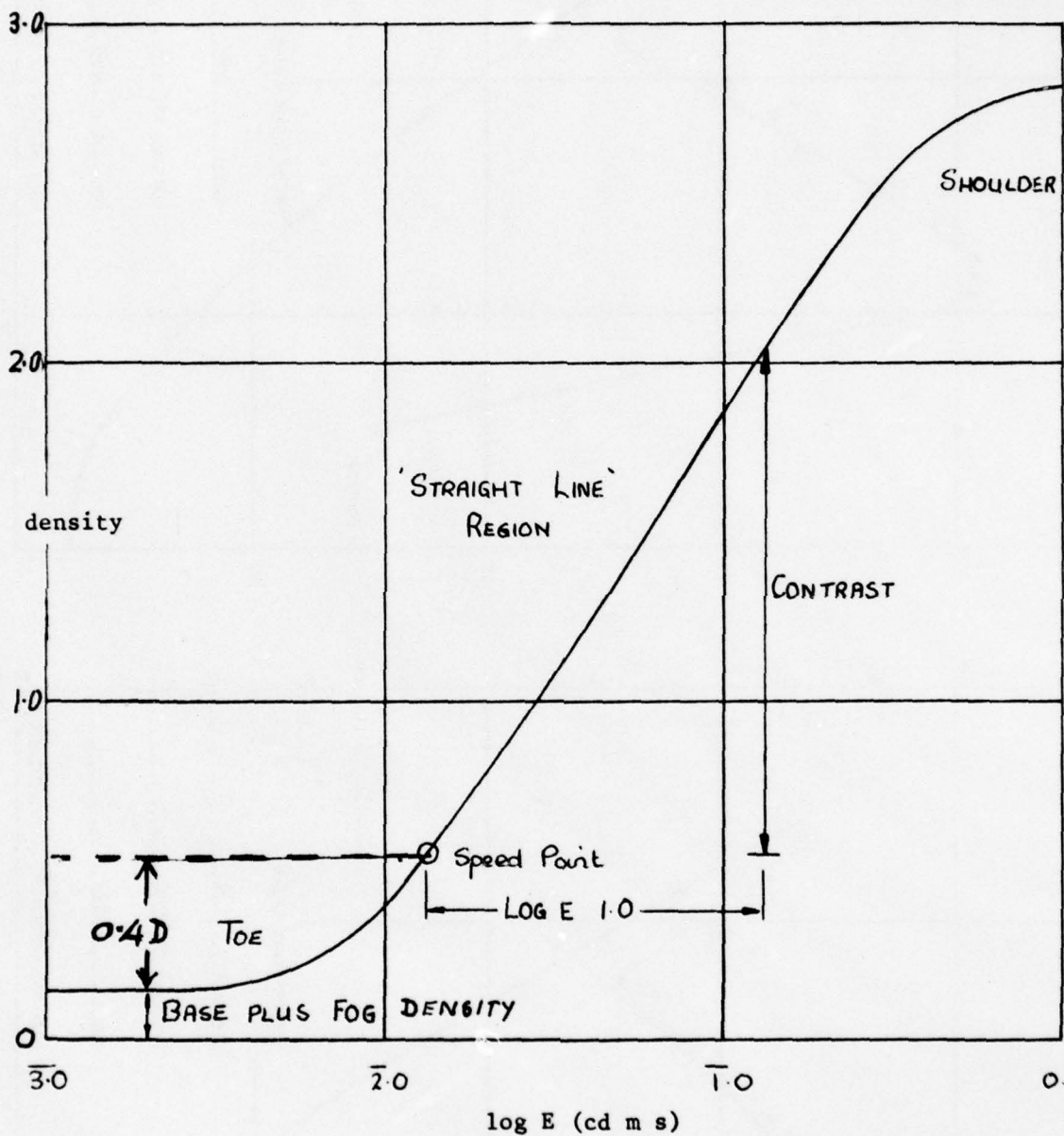
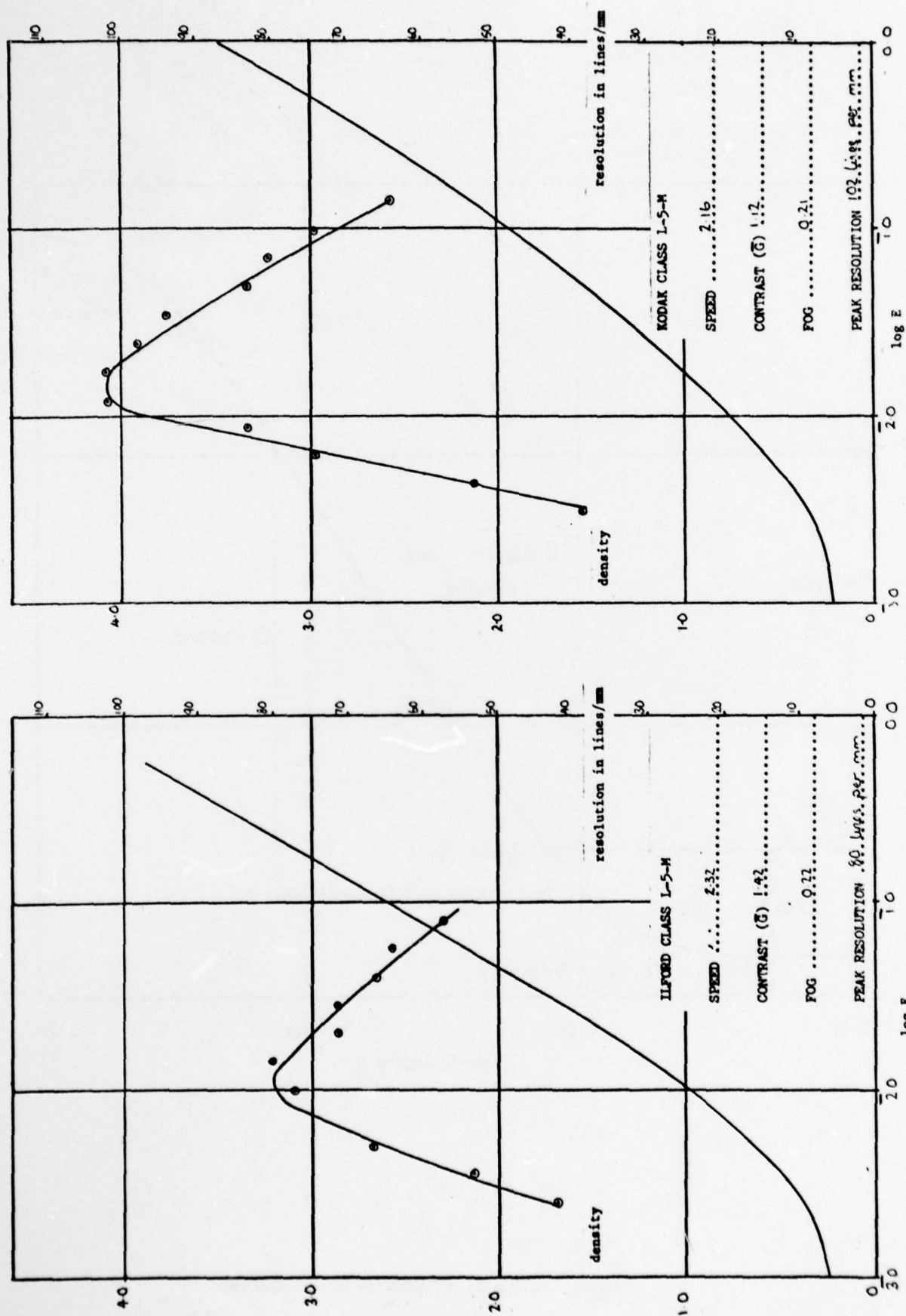


Fig 6 Typical characteristic curve

Fig 7



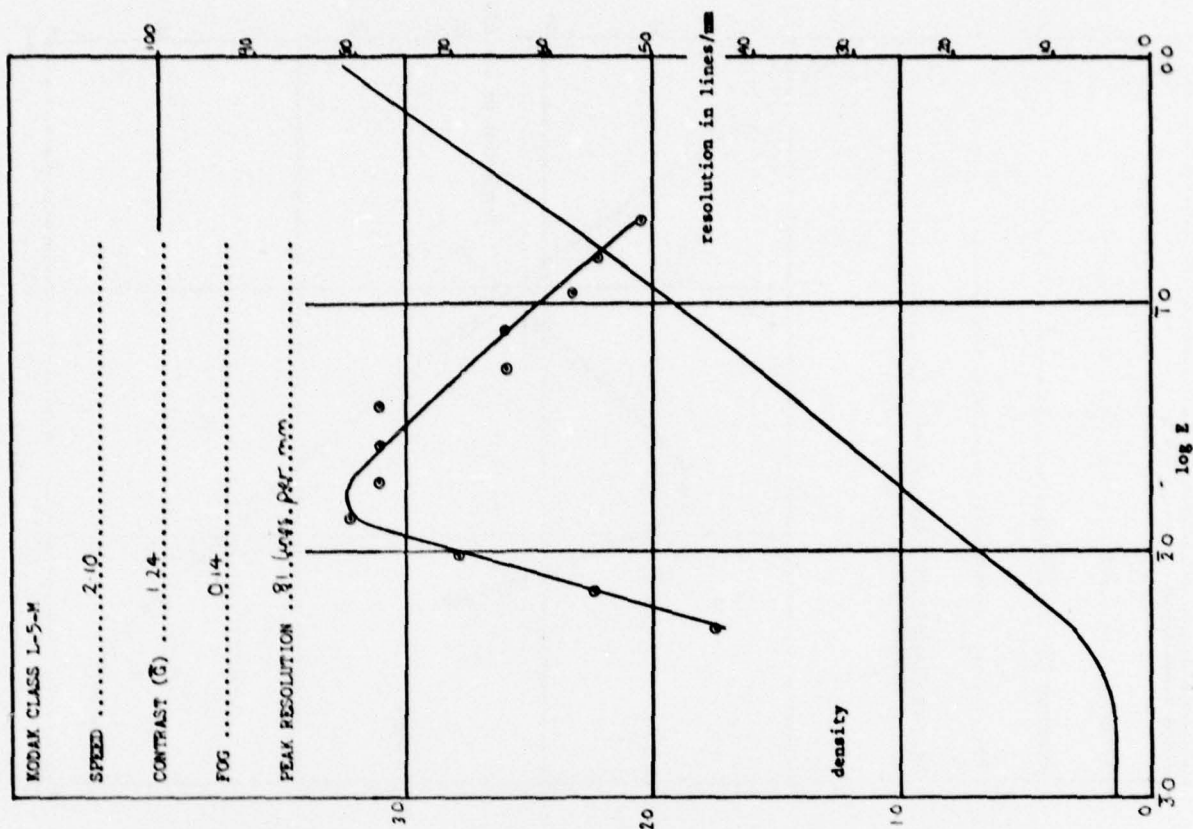
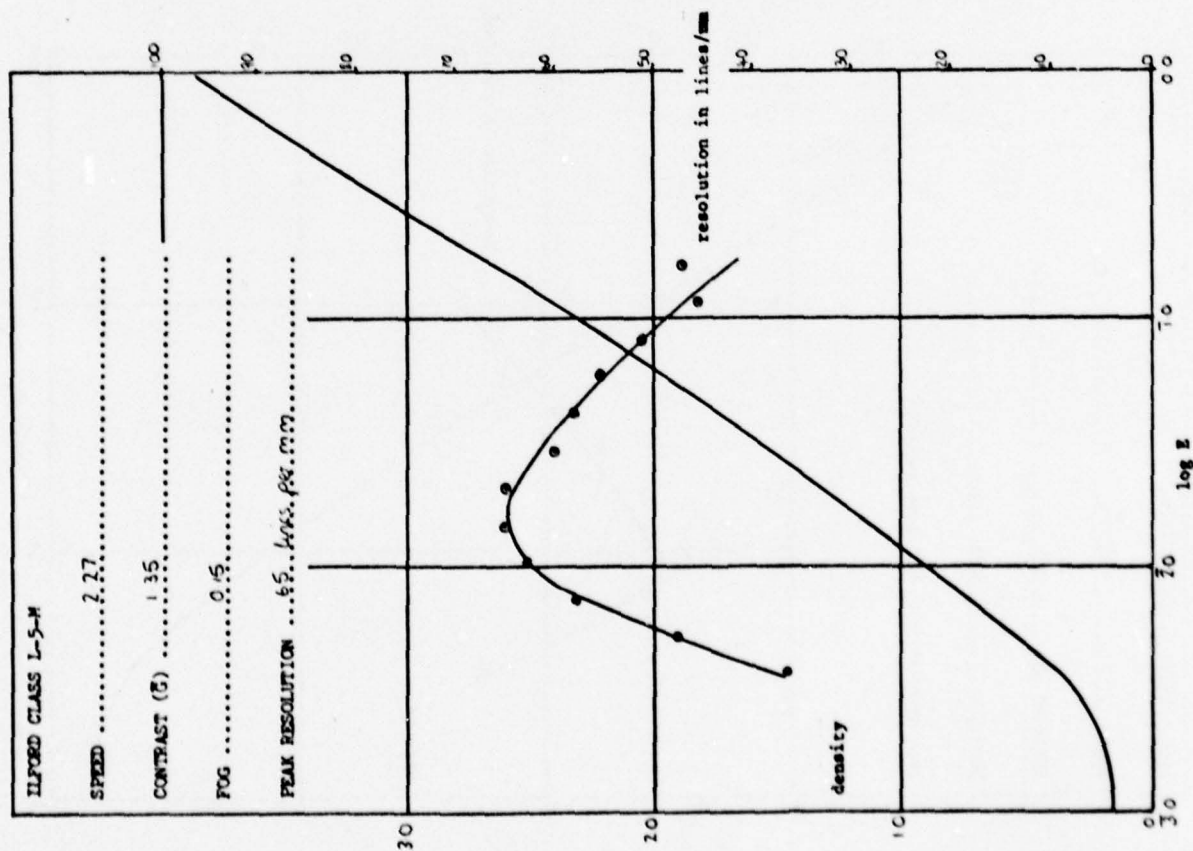


Fig 8 Characteristic and resolution curves for target modulation 0.58

Fig 9

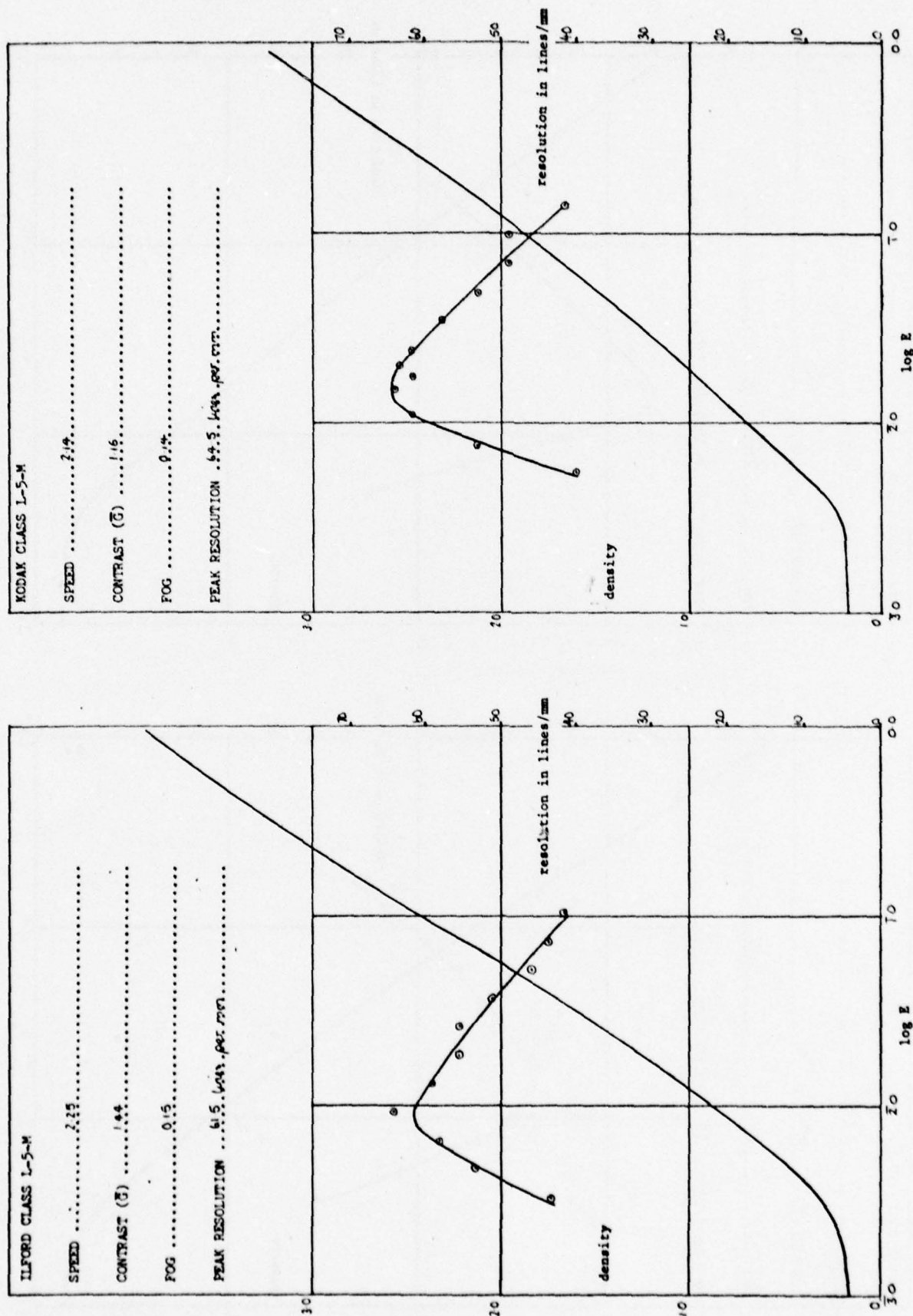


Fig 9 Characteristic and resolution curves for target modulation 0.51

Fig 10

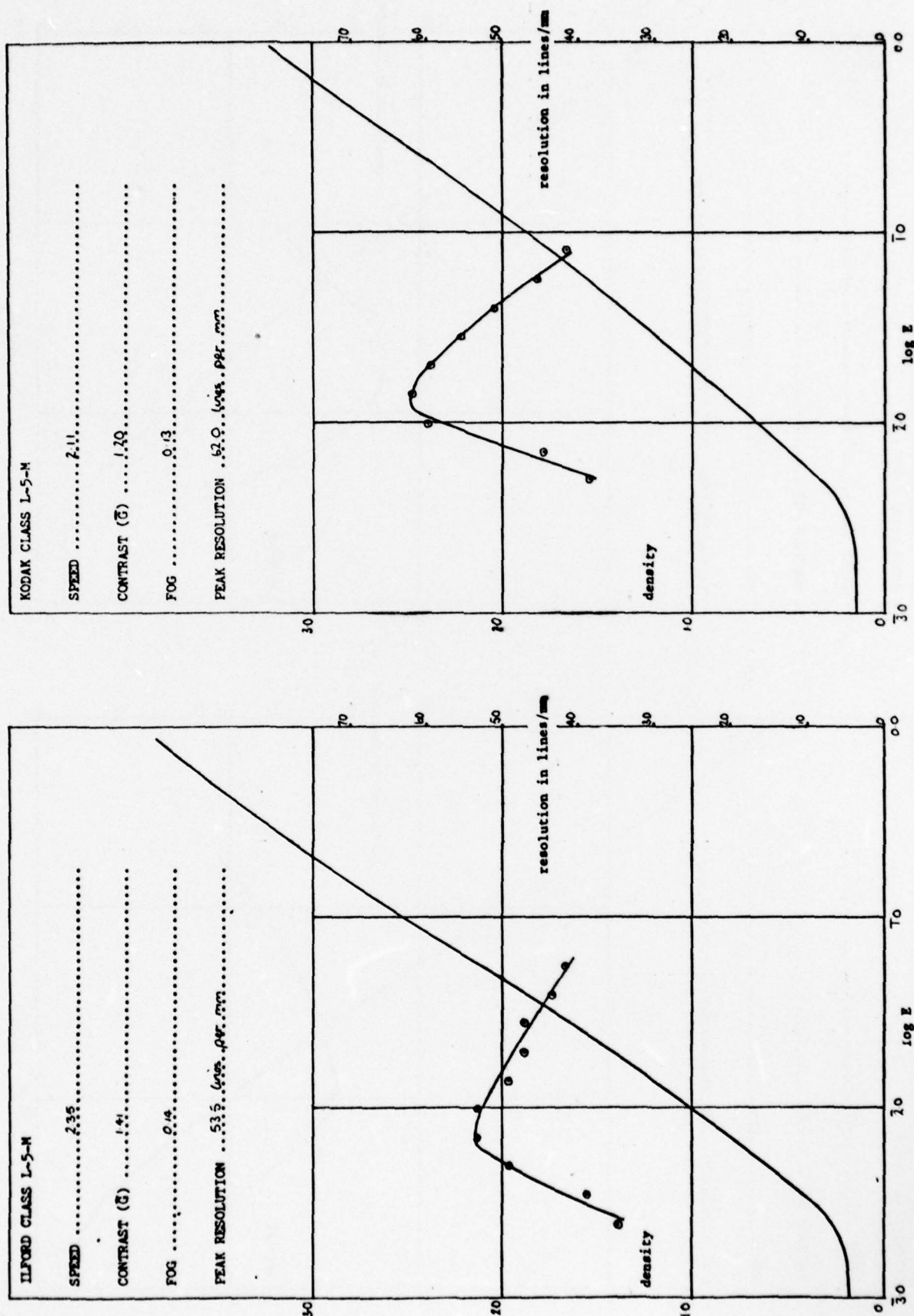


Fig 10 Characteristic and resolution curves for target modulation 0.4)

Fig 11

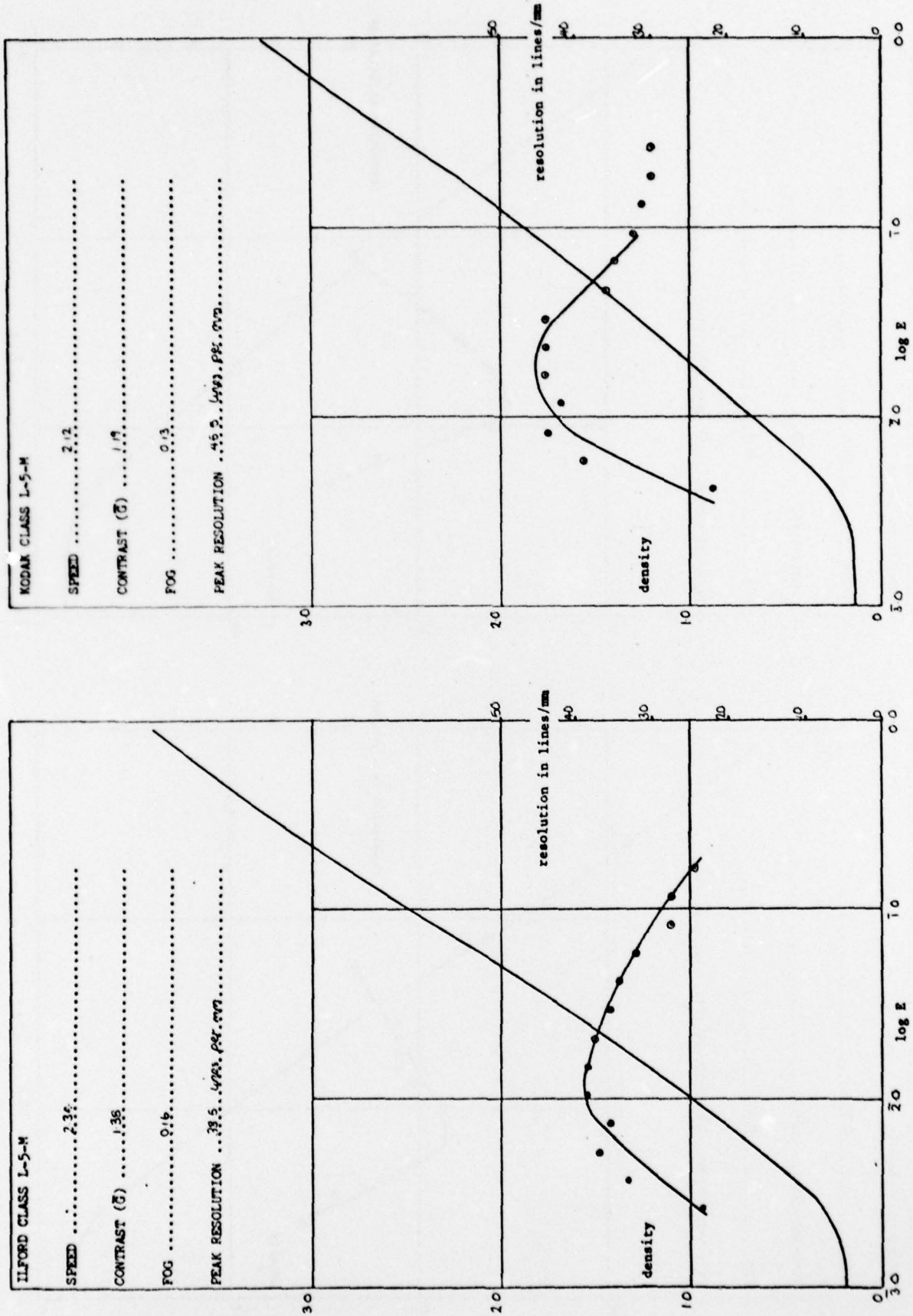


Fig 11 Characteristic and resolution curves for target modulation 0.31

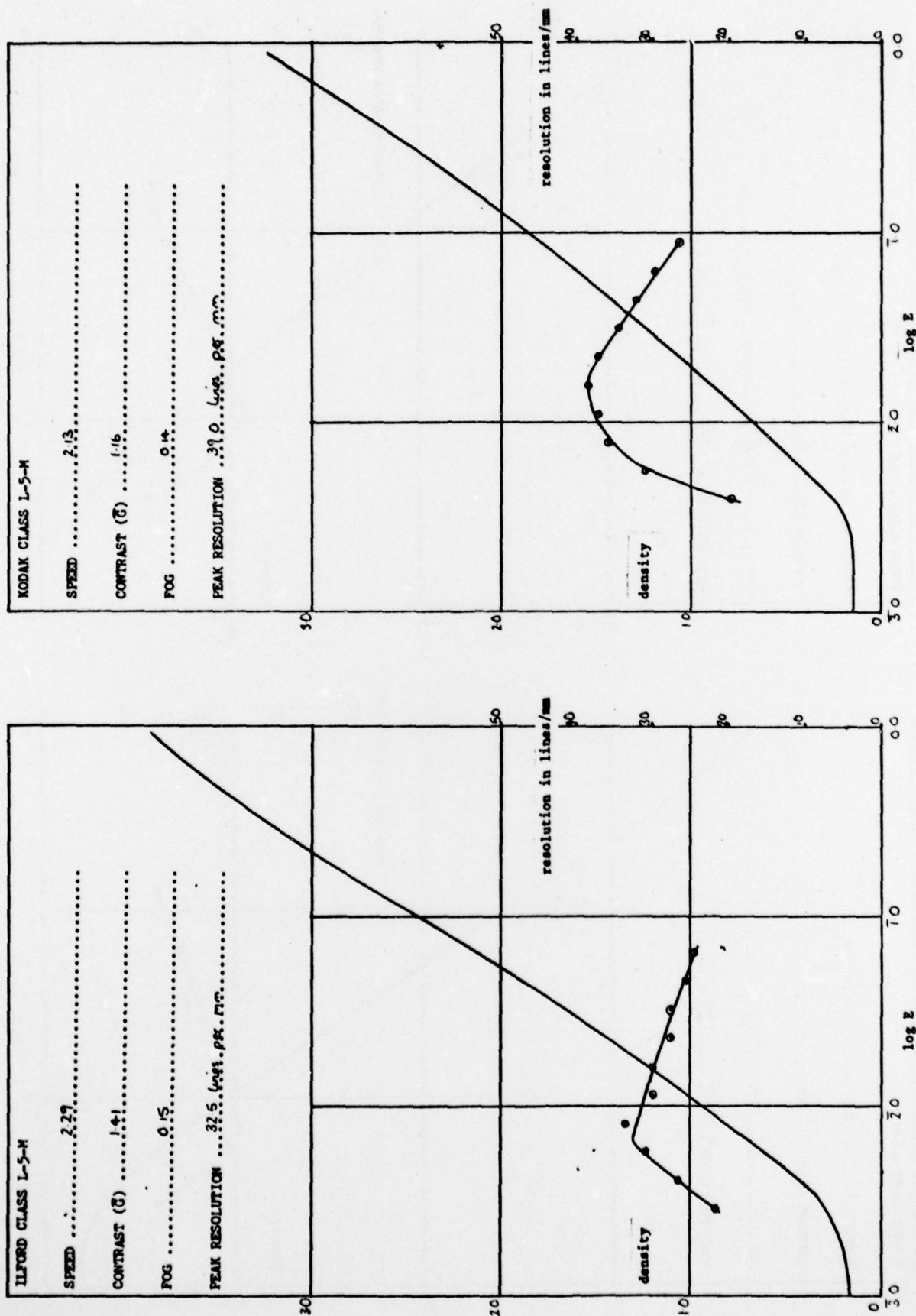


Fig 12 Characteristic and resolution curves for target modulation 0.21

Fig 13

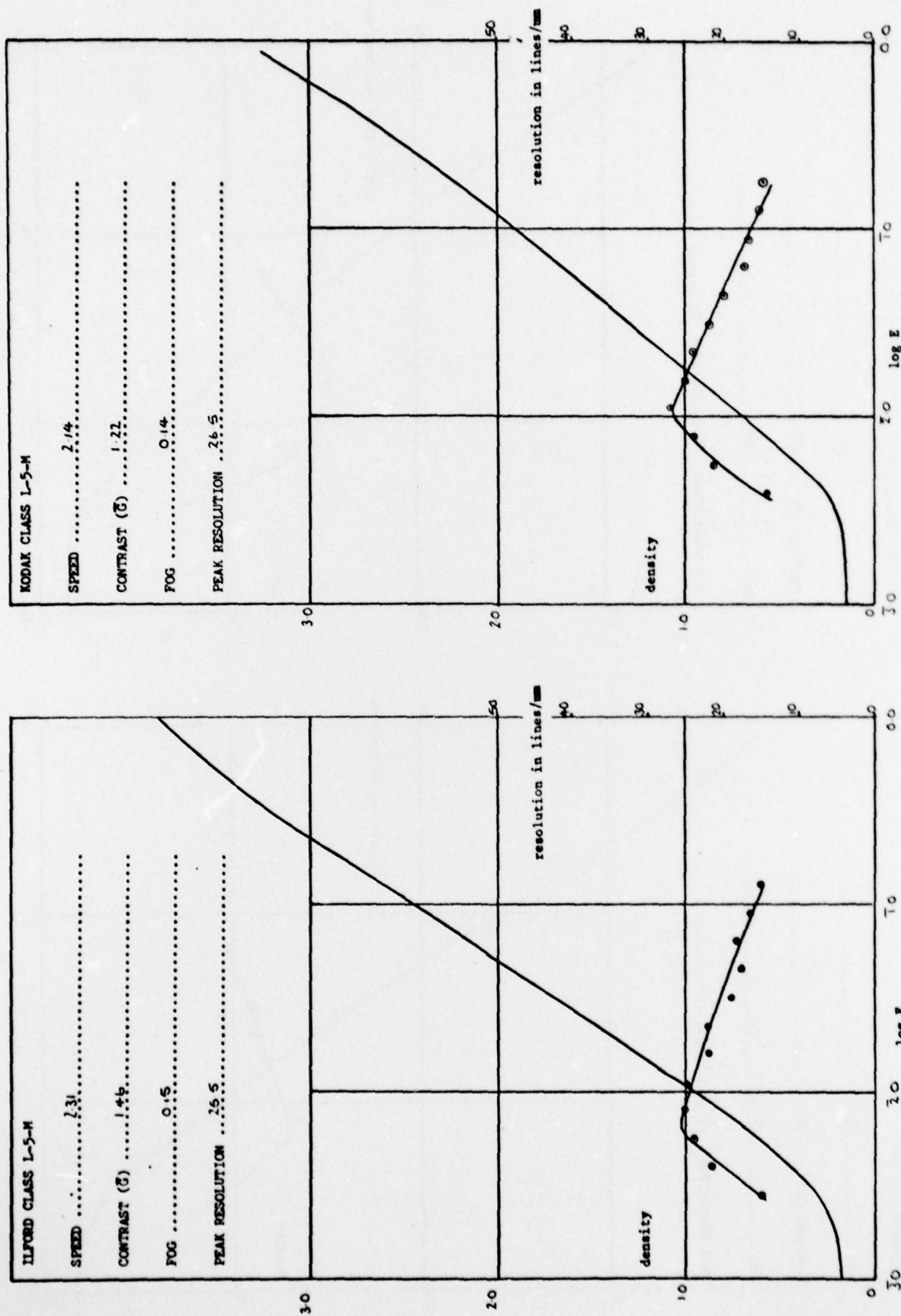


Fig 13 Characteristic and resolution curves for target modulation 0.14

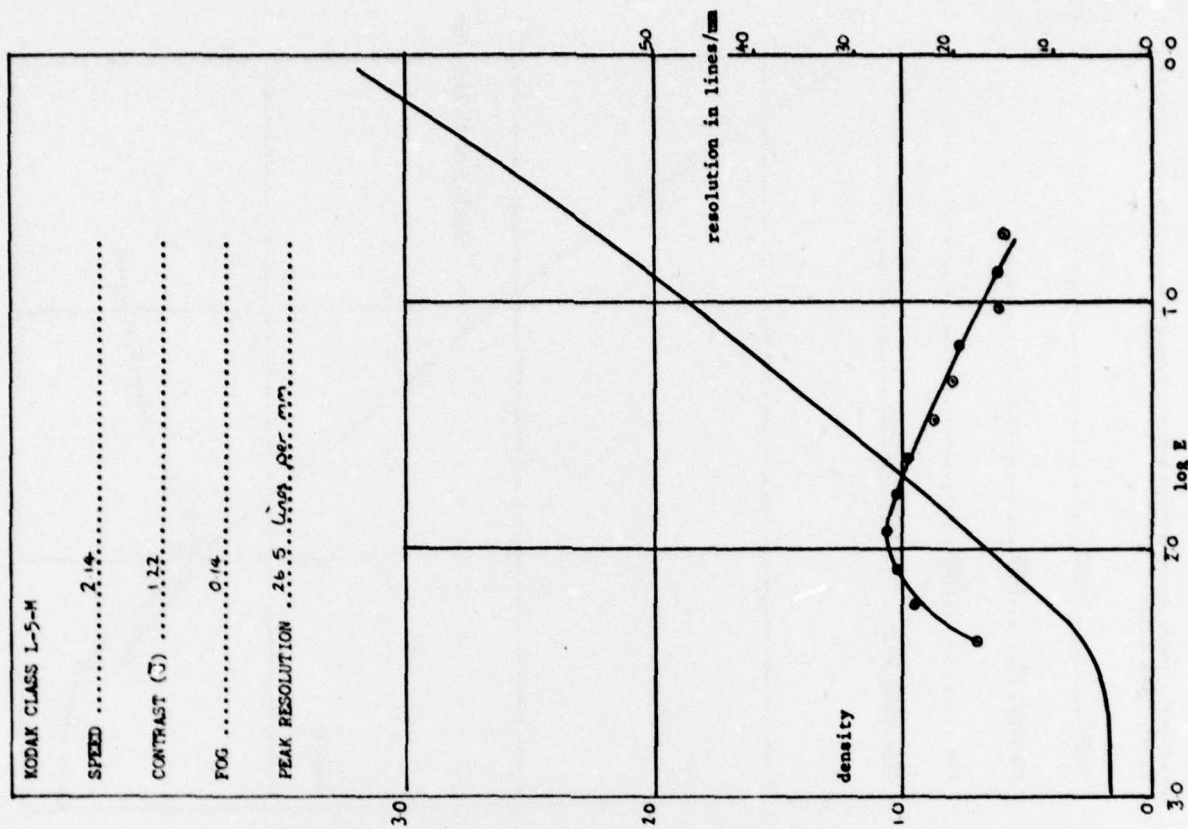
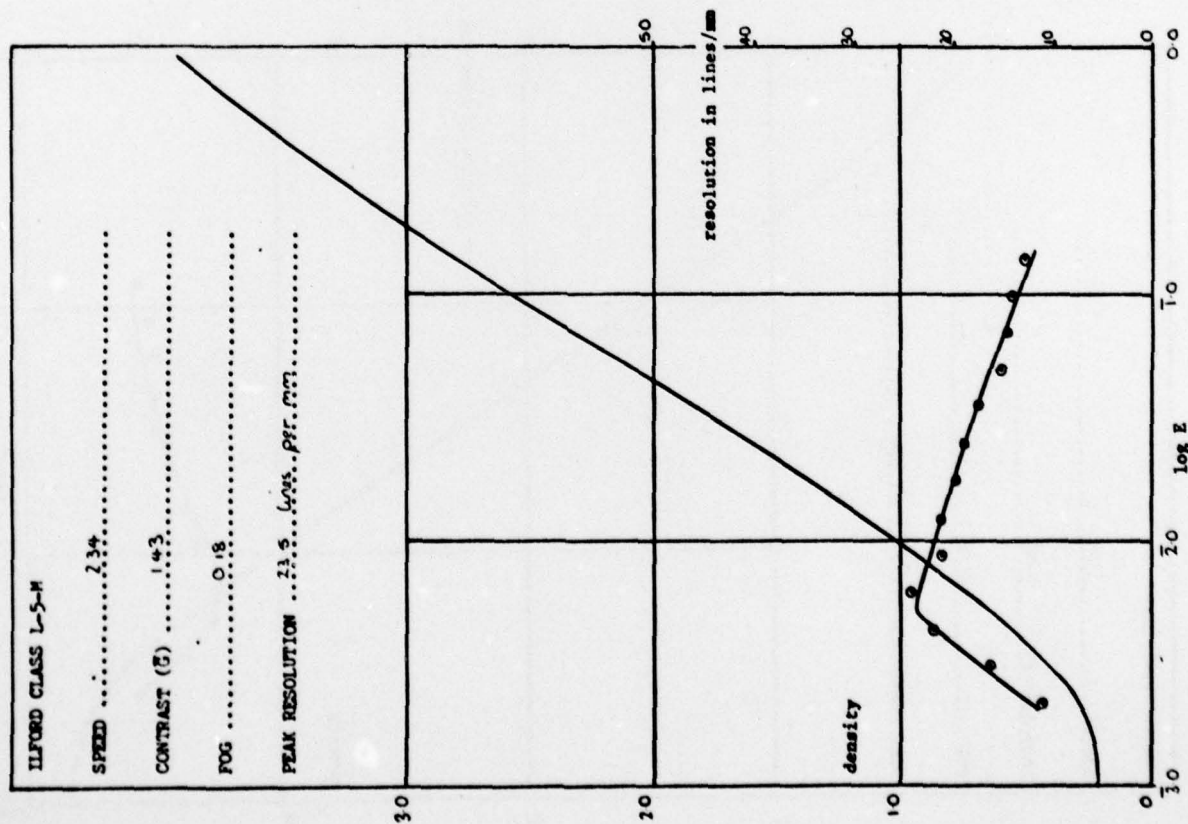


Fig 14 Characteristic and resolution curves for target modulation 0.13

Fig 15

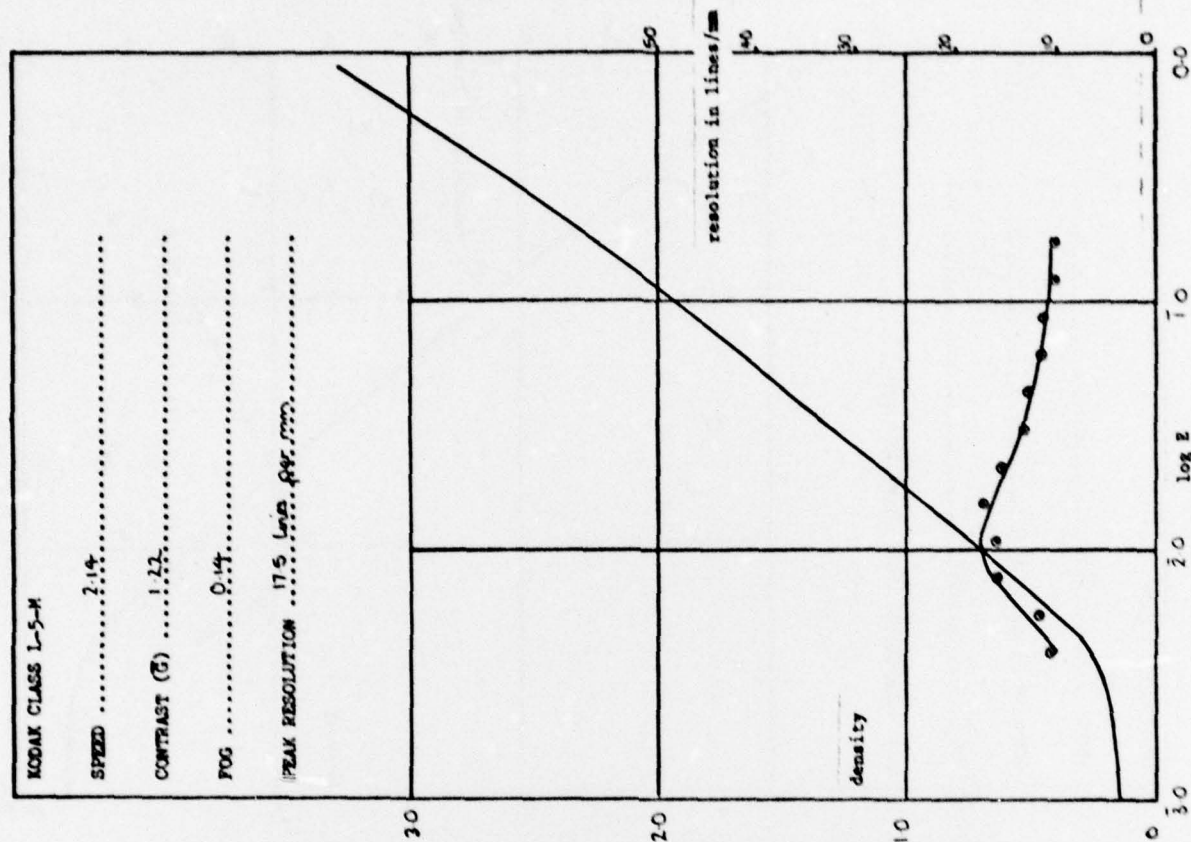
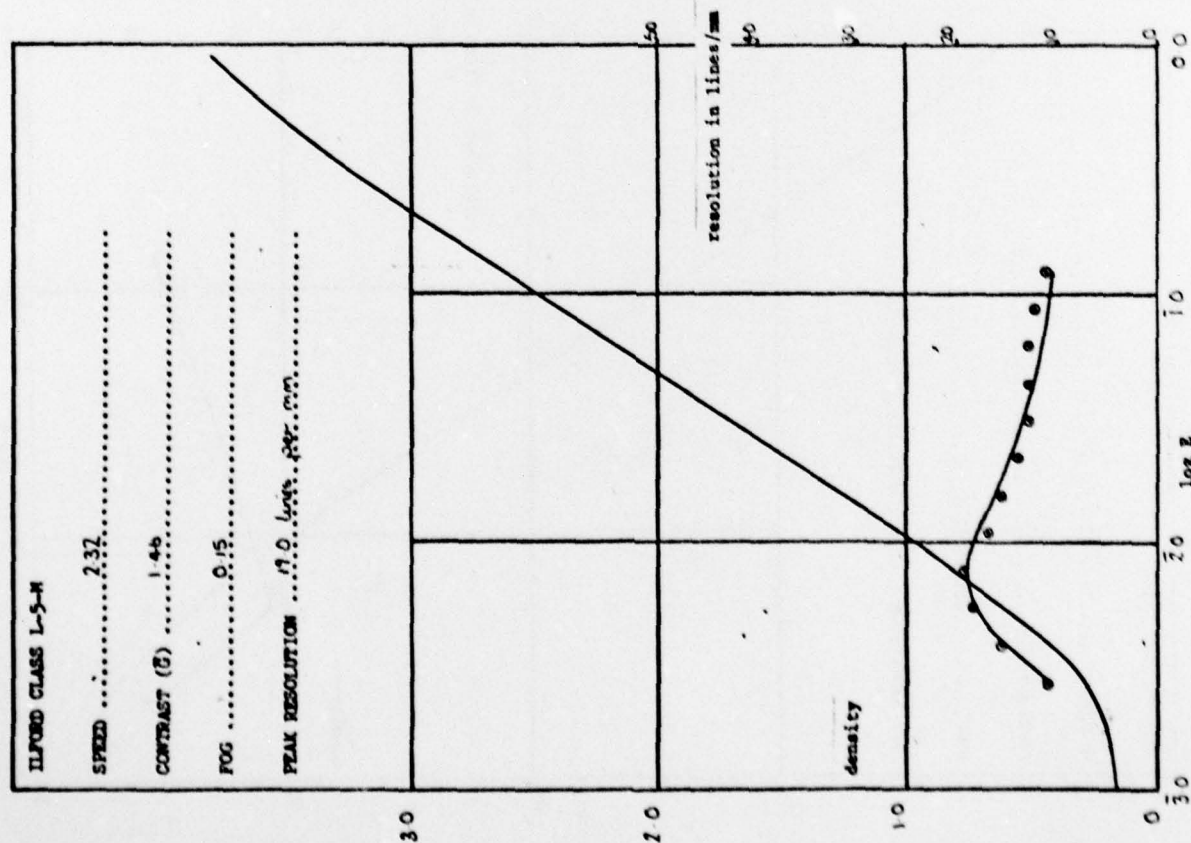


Fig 15 Characteristic and resolution curves for target modulation 0.09

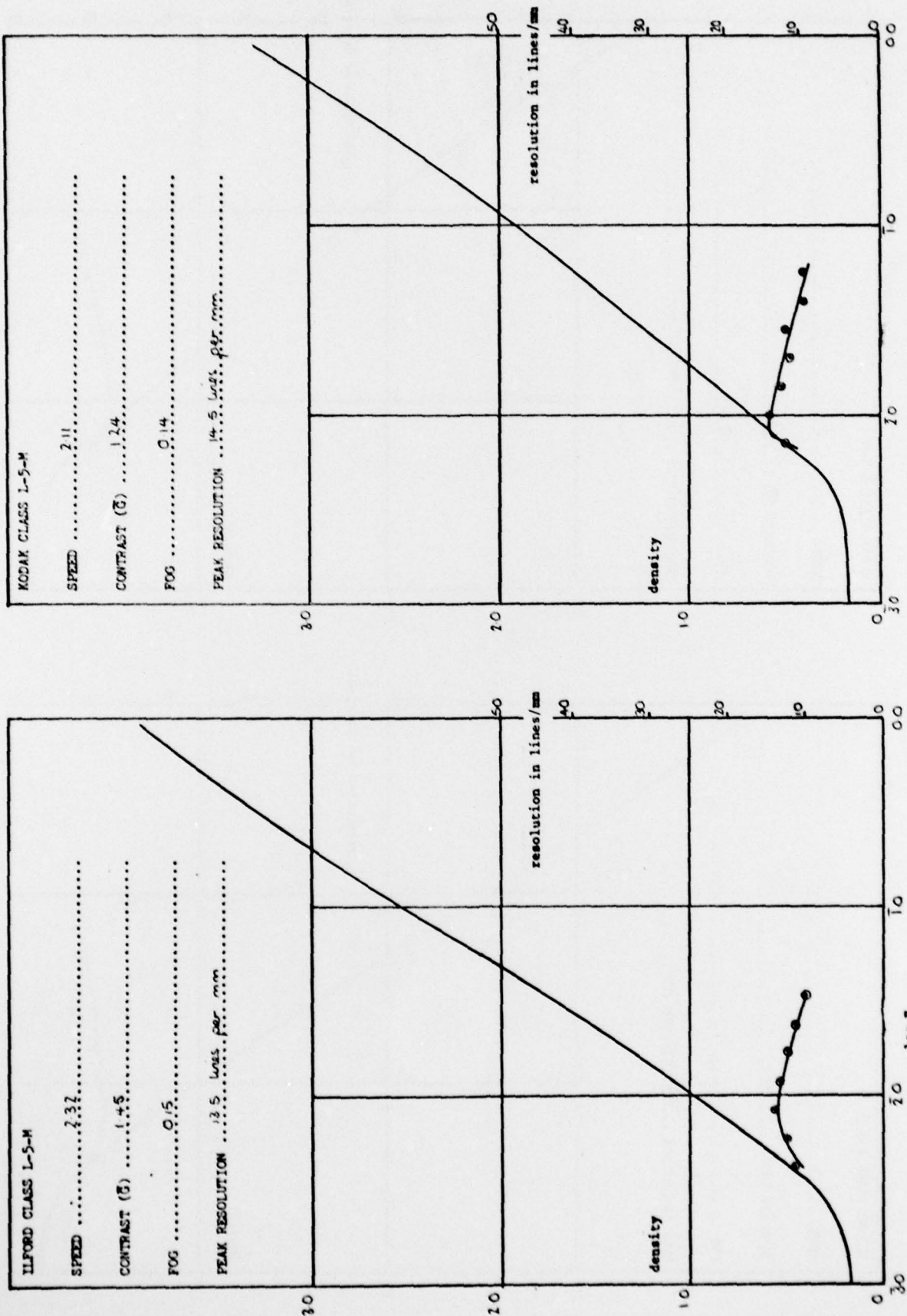


Fig 16 Characteristic and resolution curves for target modulation 0.07.

Fig 17

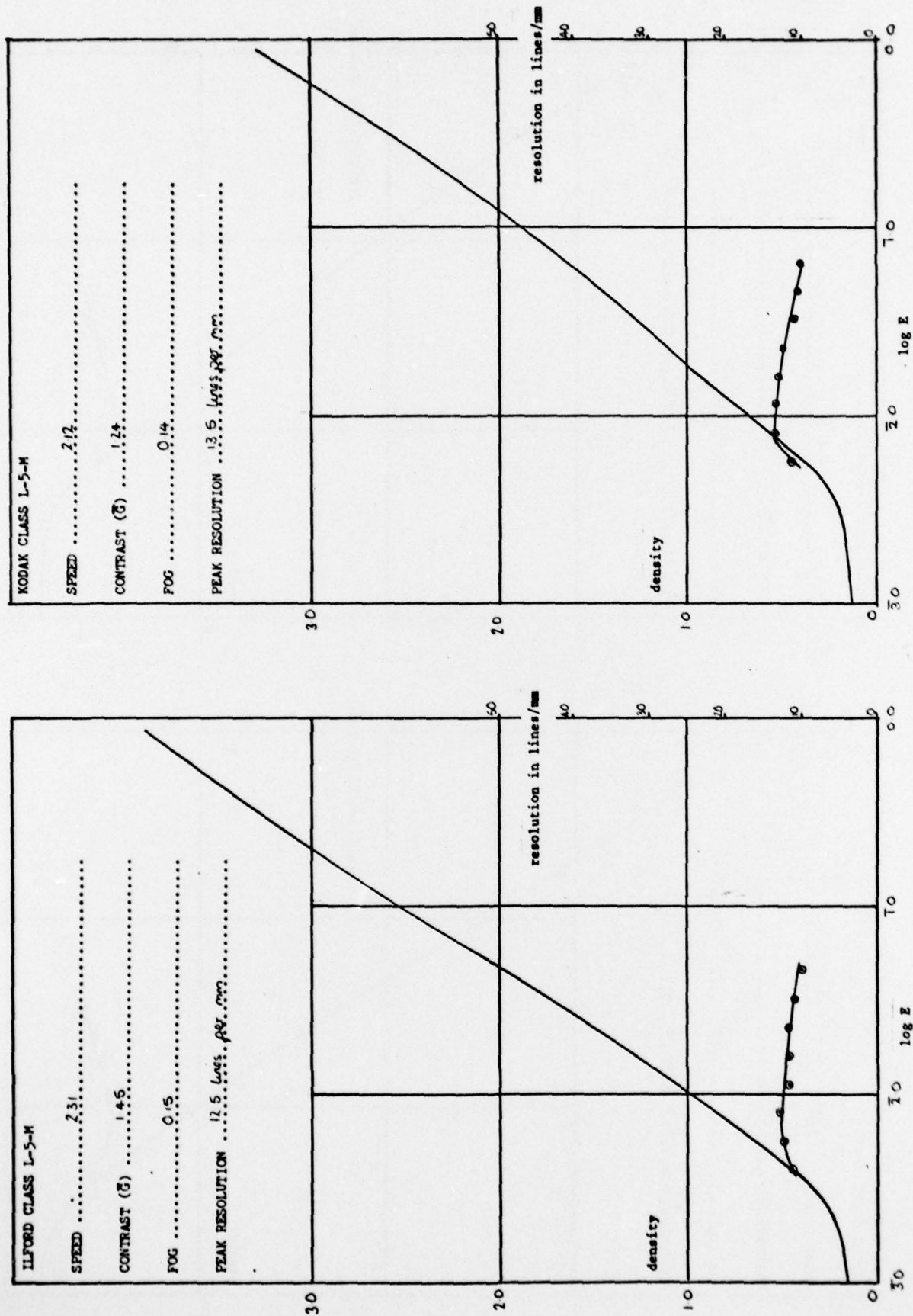


Fig 17 Characteristic and resolution curves for target modulation 0.058

Fig 18

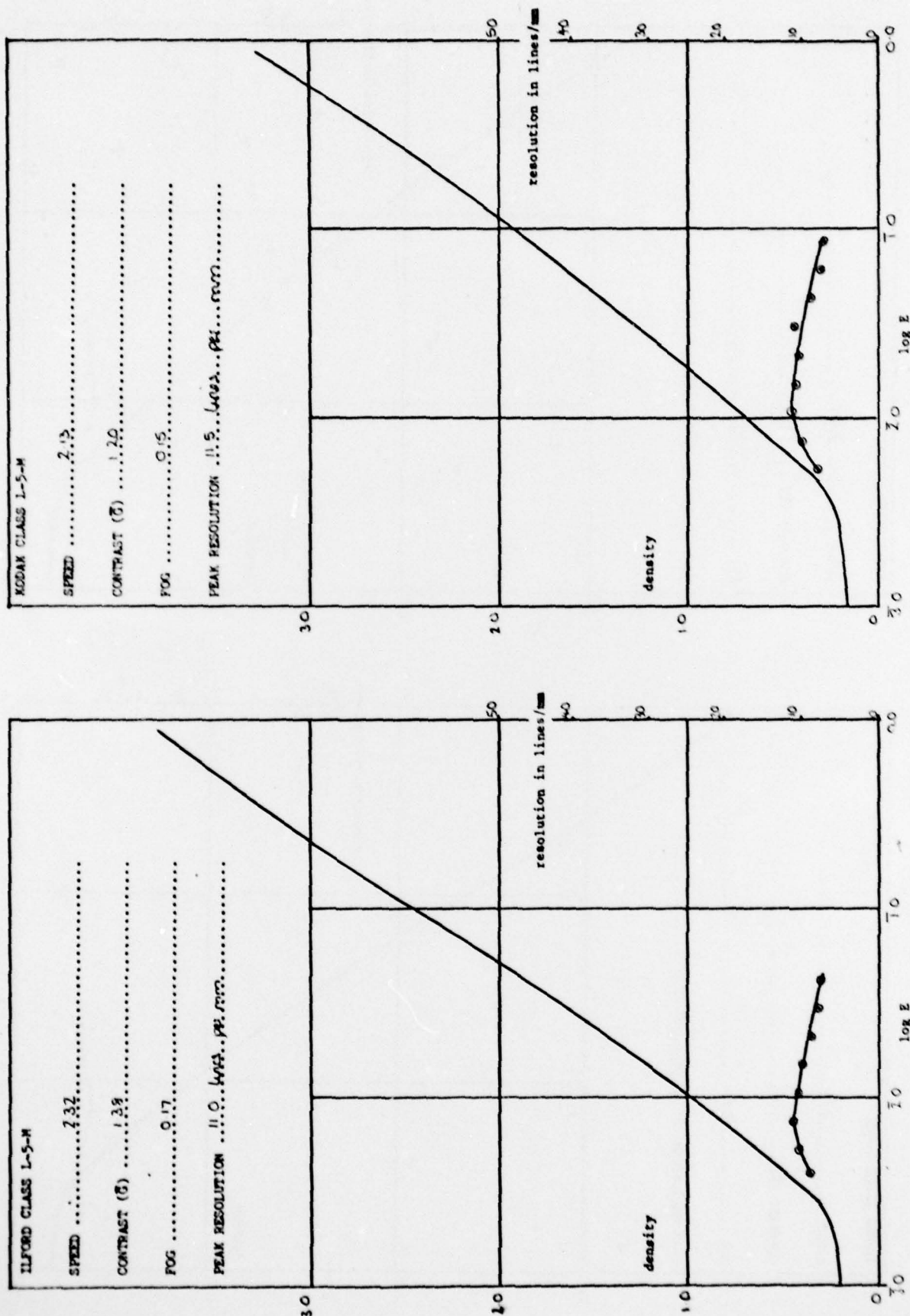
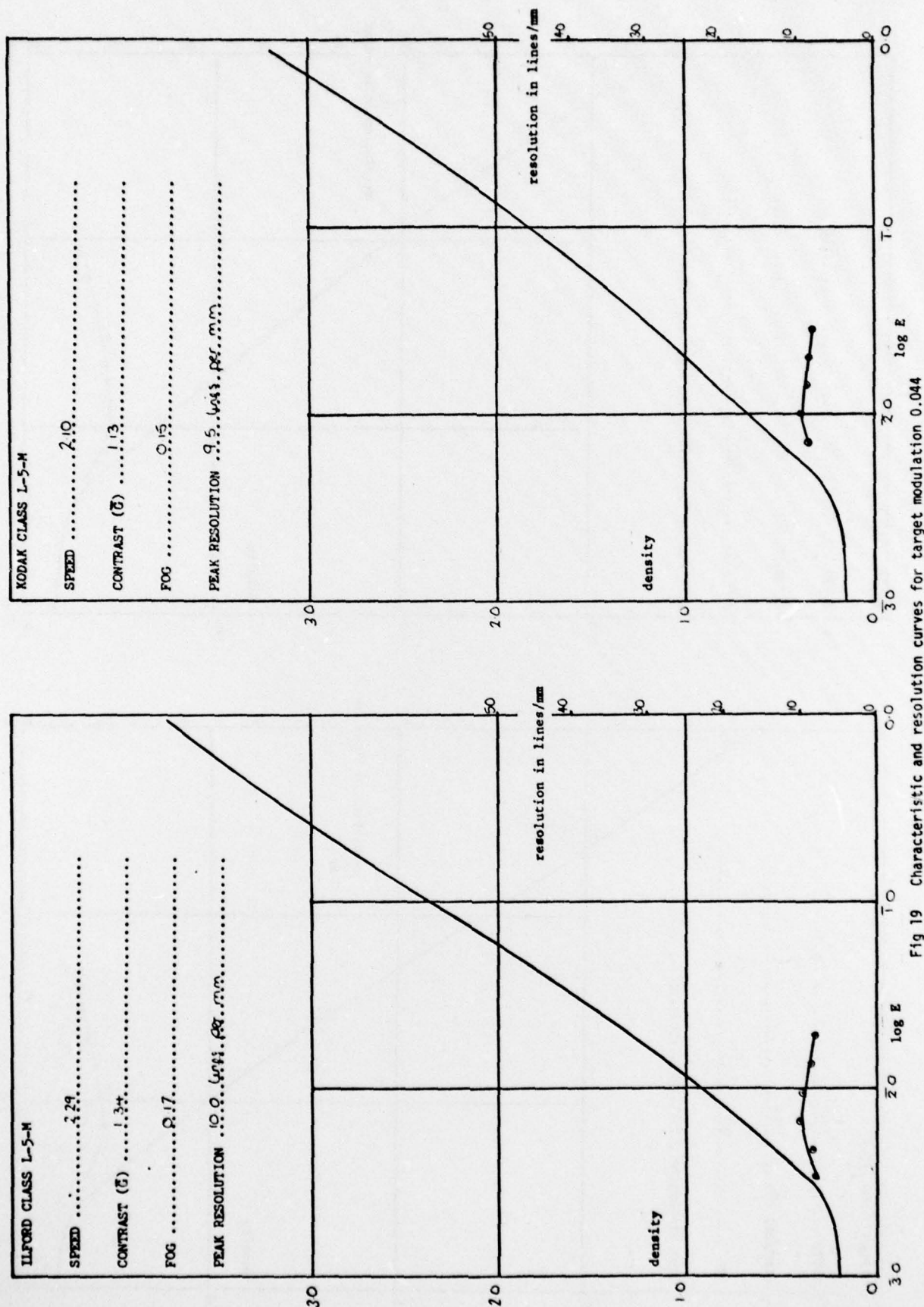


Fig 18 Characteristic and resolution curves for target modulation 0.052

Fig 19



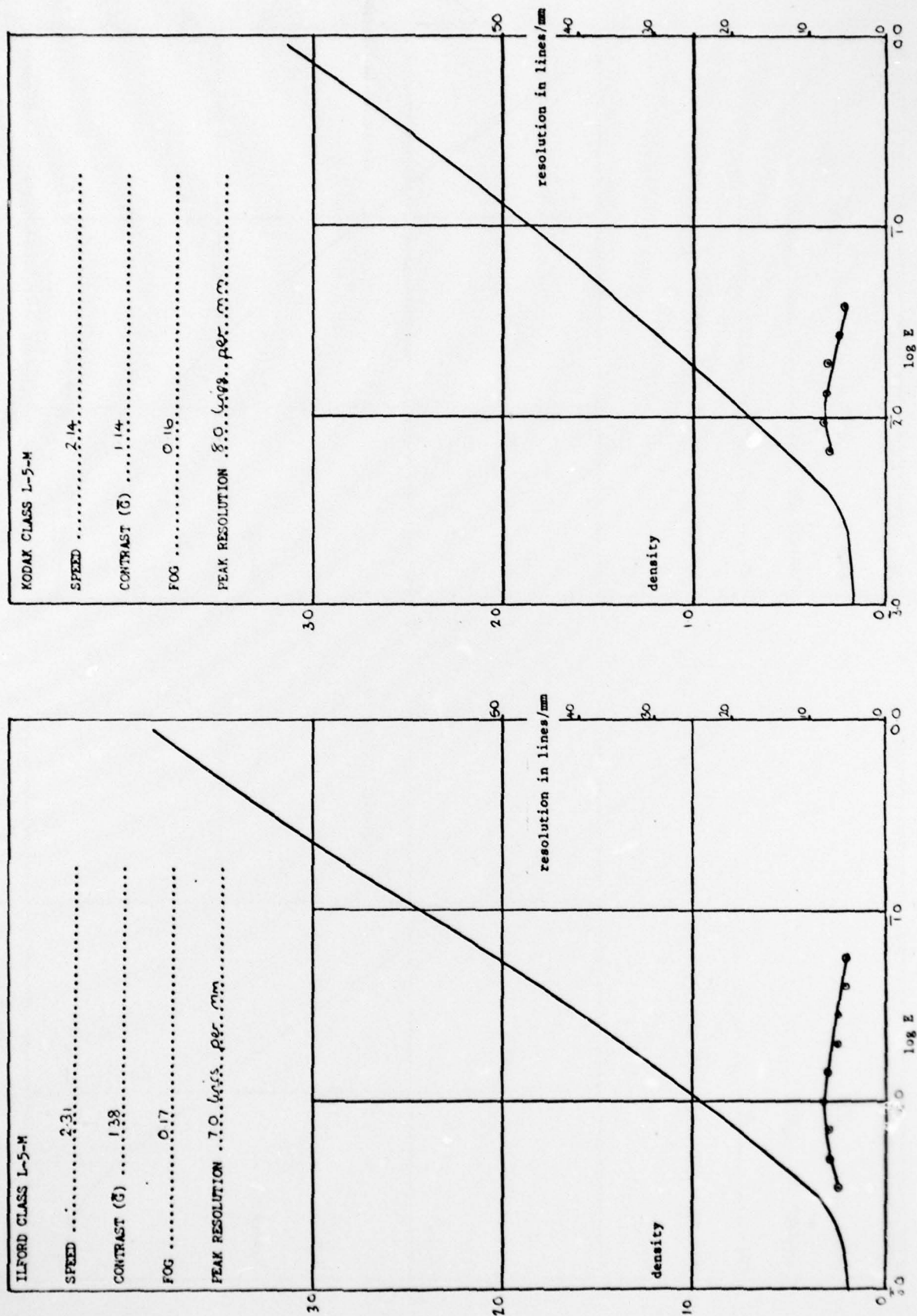


Fig 20 Characteristic and resolution curves for target modulation 0.038

Fig 21

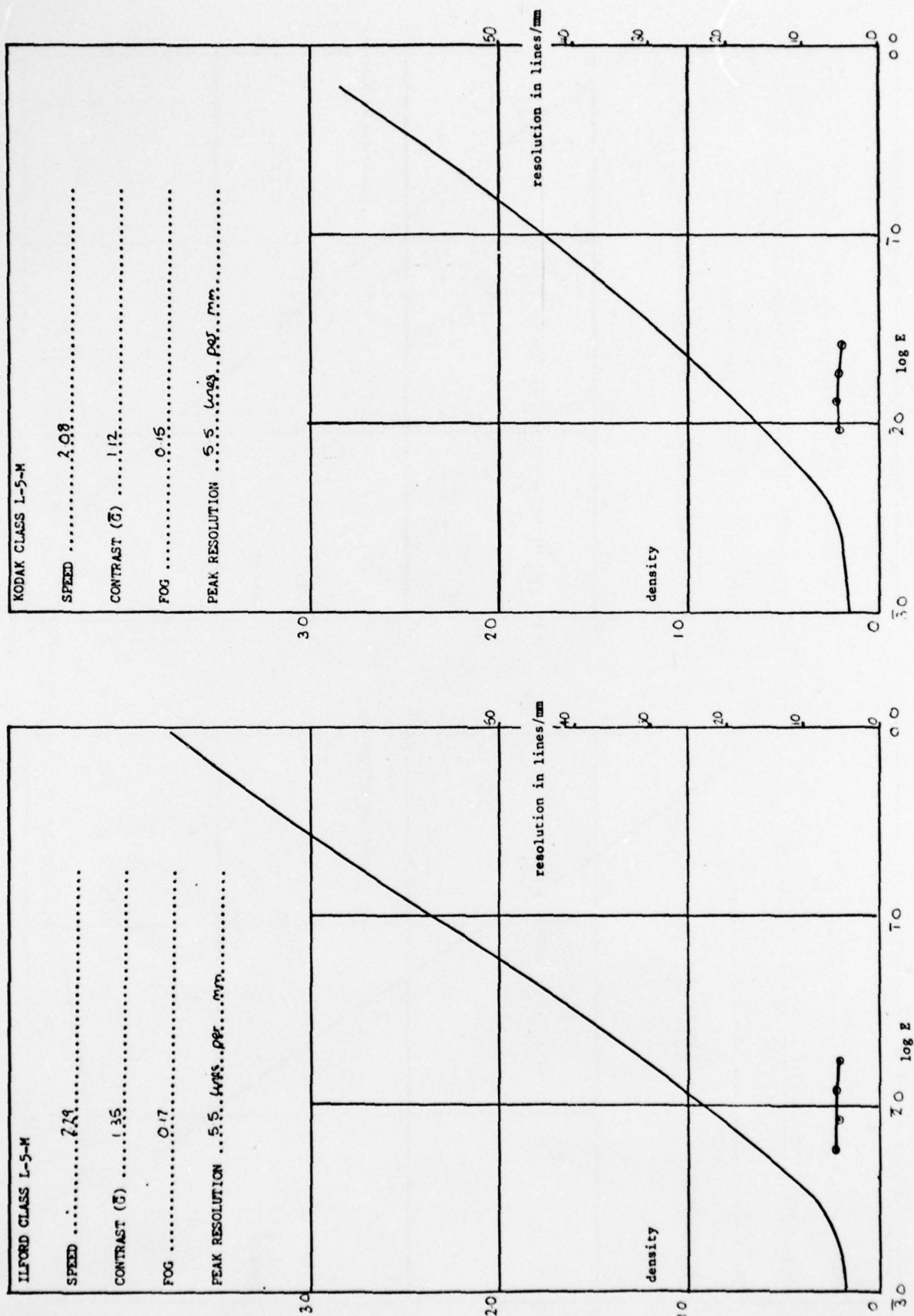


Fig 21 Characteristic and resolution curves for target modulation 0.024

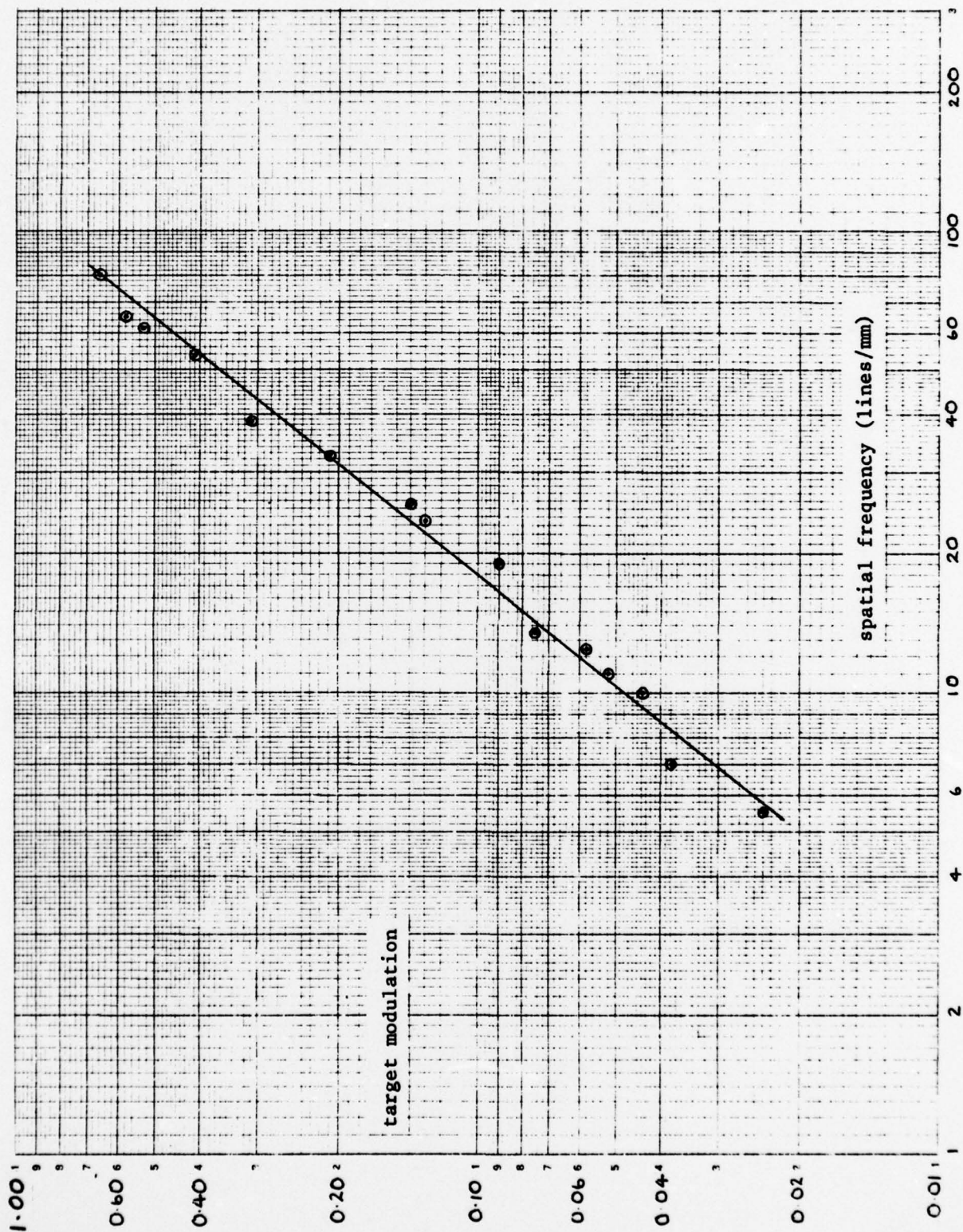


Fig 22 Film threshold modulation curve for Ilford Class L-5-M

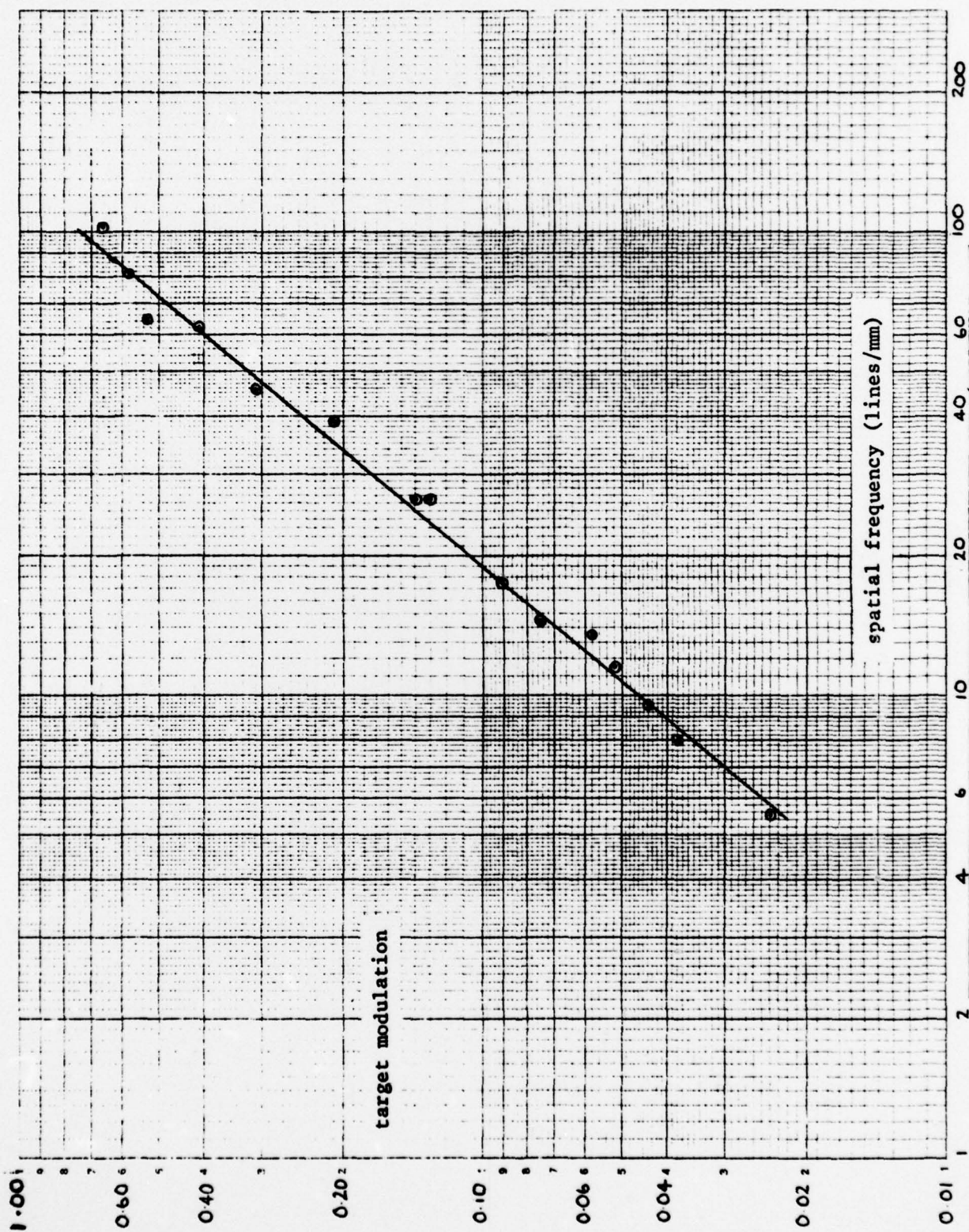


Fig 23 Film threshold modulation curve for Kodak Class L-5-M

REPORT DOCUMENTATION PAGE

Overall security classification of this page

UNLIMITED

As far as possible this page should contain only unclassified information. If it is necessary to enter classified information, the box above must be marked to indicate the classification, e.g. Restricted, Confidential or Secret.

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17. Abstract <p>The Film Threshold Modulation is a measure of performance which can be combined with lens Modulation Transfer Function figures to give an assessment of lens/film performance.</p> <p>This Memorandum describes the techniques developed for obtaining the Film Threshold Modulation Curves for any type of film using a Resolution Camera. The results achieved for the two films tested (Kodak and Ilford Class L-5-M) are also presented.</p>					

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